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PREFACE.

THE present volume is the first of a series which comprises the following—Draining and Embanking, Irrigation and Water Supply, Roads and Fences, Farm Buildings, Field Implements and Machinery, Barn Implements and Machinery, and Agricultural Surveying.

The existing literature on these subjects is by no means sparse, but there is no work of recent date which deals with them in a complete or connected form; while the old text-books on such matters, however good they may have been in their day, are now rendered more or less obsolete and untrustworthy, by reason of the great advances which have been made in agricultural science and mechanics within the last few years.

To bring forward all recent information and improvements in connection with the subjects treated of, and to preserve all that is good and practicable, while avoiding what is obsolete or misleading, in the older text-books, gives ample scope and fitting material for the work here begun.

In regard to Land-drainage, which forms the main topic of the present volume, it is abundantly clear, from the effects of a few wet years, that not only is there great need of its extension, but that serious deficiencies exist in much of the drainage already done, and that in the majority of cases the improvement is less durable than it has been common to suppose.

There is very little land that is not in need of draining. For the object of drainage is not merely to dry land, and to carry off the surplus water, but also to let water into the soil, to enrich the soil by taking advantage of the fertilising rain, to counteract drought, and to create a healthy renovation of both air and water, from the surface downwards to the drain level.

The failure of drainage, in certain instances, to lay wet land sufficiently dry for cultivation or stock-raising, is found to be attributable to such causes as errors in principle, rule-of-thumb work, and neglect to cultivate deeply after draining; and a revision of the practice of land-drainage is the natural outcome of the experience thus recently gained.

The once much controverted question of deep or shallow drains has in effect settled itself, and in favour of no particular theory. Experience has taught those interested in the problem, that in order to drain successfully, the depth of the drains must be regulated by the width or distance between them; and that again by the

nature of the soil and subsoil; while the cost of the improvement puts a practical limit to both the depth and frequency of the drains.

Another change in the practice of draining is the employment of larger-sized drain-pipes than it has hitherto been customary to use.

The increased cost of labour is forcing attention to the economy of moving the least possible quantity of earth in cutting the drains, and of superseding hand cutting by machine draining as far as practicable.

Embanking is treated of in the same volume, from its being a necessary preliminary to the drainage of tidal lands.

NOTE TO THE SECOND EDITION.

In this Edition some clerical errors have been corrected, and a few explanatory paragraphs added in the body of the book. While the Appendix has been enlarged by the addition of a short description of a Drain Pipe Machine.

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DRAINING AND EMBANKING.

CHAPTER I.

REASONS FOR DRAINING LAND.

LAND-DRAINAGE, by which we signify the art of removing the excess of water from the soil, appears to have been practised, in one form or another, nearly as long as agriculture itself. Open channels would first naturally suggest themselves as the easiest means of relieving the soil of superabundant moisture. But as land increased in value, and the number of trenches had to be multiplied, it would soon be felt that by covering over those open channels they would still perform their office, and yet leave the space occupied by them available for tillage and cropping. There are other reasons, as the sequel will show, why under-draining is preferable to open or surface draining.

Objects of Draining.—The primary objects of under-draining undoubtedly are—to carry off stagnant water; to give a ready escape to the excess of what falls in rain; and to arrest the ascent of water from beneath, whether by springs or by capillary action; so as to render the land sufficiently dry for cultivation, and at the same time regulate the supply of moisture to the growing plants.

But the purpose of under-draining is not merely to let water out of the soil. We drain to let water into the soil, as much as to take it out—not merely to carry off the surplus water, but to make the fertilising rain filter through the soil. "No farmer worthy of the name," says an authority, "would wish to conduct rain-water off his land by surface grips, or have recourse to under-draining simply to tap the soaking subterranean springs."

Effects of Drainage.—"When there is an excess of water in a soil, and no provision exists for withdrawing it, the interstitial canals become completely filled, to the exclusion of the necessary amount of air, on which the activity of the soil considered as a laboratory for the production of plant food depends.

"When the soil is under-drained, the superfluous water flows off through the air canals, and only so much moisture is retained as can be absorbed by the minuter pores of the soil; and as there is, then, free communication, through the canals, between the pores and the drains, it is evident that the water will all be withdrawn from the soil except that which is held by capillary attraction. Thus the rain which falls upon, and is absorbed by, the surface ground, percolates towards the drainage level, flushing every crevice and canal in its descent, leaving behind it the nutritive ingredients which it carries in suspension or in solution, and on which the plants can feed as it passes by their roots, or which the soil, acting as a filter, extracts and appropriates."

According to Way, the total quantity of nitrogen, in the form of ammonia and nitric acid, brought down by rain and snow upon an acre of land in the year, was found to be 6·63 lbs. in 1855, and 8·31 lbs. in 1856.

Under-draining not only allows the rainfall loaded with this fertility to pass through the soil and be discharged from underneath, after depositing its fertilising material, instead of flooding the surface and removing from the upper soil many substances useful to vegetation; but the rain-water in sinking down through the soil oxidises and washes out of it anything that may be hurtful to the roots of plants; and the solvent action of the rain-water is, at the same time, brought to bear upon the inert constituents of the soil and of the manures with which it is brought into contact. The latter is not the least benefit of draining, for on wet land the best manures are almost thrown away.

"This constant descent of water through the soil causes a similar descent of air through its pores, from the surface to the depth of the drain. When the rain falls it enters the soil, and more or less completely displaces the air which is contained within its pores. Thus air either descends to the drains, or rises into the atmosphere. When the rain ceases, the water as it sinks again leaves the pores of the upper soil open, and fresh air consequently follows. Thus, where under-drains exist, not only does every shower deposit its fertilising ammonia, but it serves to force the fresh air through the pores, which produces conditions so healthful to vegetation."

Under-draining deepens the soil by lowering the line of excessive water beyond injury to the roots. It affords to plants a deeper soil for their roots to penetrate, at the rate of 100 tons per acre for every inch of depth gained. It prepares the way for deep tillage and steam cultivation. It improves the texture of the soil by making it more porous, drier, looser, and more friable; and it thus not only gives greater ease in

tillage operations, but admits of the land being worked sooner after a fall of rain. The difference in labour between ploughing drained and undrained land is very considerable, and at the lowest estimate cannot be put at less than one shilling per acre for each ploughing.

Thorough drainage not only relieves a soil of excess of water, but, strange as it at first appears, it greatly mitigates the effects of dry weather. When soil is drenched with water and dried by evaporation, it becomes hard, especially if it be of a clayey nature. Land that is dried by drainage is absorbent and retentive of moisture dropped by dews and acquired from the atmosphere; while the soil deepened by drainage permits growing crops to put forth longer roots, and thus become secured against drought.

By drainage, the temperature of the soil is raised in summer as much as 3°, which is in effect to transport the land 150 miles southwards. The soil is thus enabled to grow a greater variety of crops than it would do in its undrained state. Less seed is required in sowing, because fewer seeds perish than when they are put into a saturated soil where the temperature is lower, and from which the air necessary to germination is excluded. It prevents in a great measure grass and winter grains being killed or thrown out by frost. An earlier seed-time and harvest are also accompaniments of drained land; the season being hastened in the spring by the land drying sooner, and enabling the cultivator to get on his land earlier by several days, a start which is maintained by the crop all through the summer. A week at seed-time or harvest often makes all the difference between the success or failure of a crop.

"In all cases the end desired is the nearest possible approach to the natural examples of the best soils resting

on pervious subsoils, where the rainfall finds a gradual passage through the soil and subsoil, sinking always where it falls, carrying generally the warmer temperature of the air into the land—carrying also many an element of plant food, which the air contains, directly to the roots of plants—carrying, too, the air itself, the great oxidiser, amidst the matters, organic and inorganic, which require its influence for their conversion into available plant food, proving, by its action as a solvent, and its passage over the immense inner superficies of the soil, an active caterer for the stationary roots. At the same time it is hindered from doing the mischief which on undrained land the rainfall cannot fail of doing. The manure particles of the soil, if they do to some extent escape through drainage, are at any rate not washed wholesale from the surface into the furrows, ditches which, in the case of undrained land, receive them without the subsoil having had a chance of retaining them." [a]

One of the benefits of under-draining is that, besides letting off water which would stagnate in the operation, the finer parts of the soil are washed in instead of out, while the water which is discharged extracts a comparatively small portion of the soil. At the same time there may be some loss of soluble nitrogen occasioned by drainage.

Loss of Nitrates by Drainage.—On comparing the composition of the manure applied to land at Rothamstead with the composition of the crops that were carted off, it was found that from one-half to two-thirds, and more at times, of the supplied nitrogen was missing. Analysis of the soil failed to account for the missing nitrogen. A considerable part of it was, indeed, found

"Soil of the Farm."

to be actually present in the soil, but it appeared to be in some state of combination unsuitable for the plants' use, as it had scarcely any effect on the crops. A still larger portion of the nitrogen was, however, not to be found in the soil; but analysis of the drainage water gave so large a content of nitrates, as to lead on to the discovery that the loss of nitrogen chiefly takes place through the drains. Knowing that ammonia is readily absorbed and firmly held by most soils, it had never been anticipated that so great a loss might occur by drainage. These investigations, however, clearly showed that ammonia, when applied to the soil, is quickly converted into nitric acid, and in heavy rains is easily washed out. This is particularly the case with ammonium salts and nitrate of sodium; but it is true of all nitrogenous matters or manures within the soil; they are readily convertible, under certain conditions, into the soluble form, which renders them specially liable to waste.

Sir J. B. Lawes has calculated that if the drainage water contains only one part of nitrogen in 100,000, there will be a loss of nitrogen equal to about 23 lbs. of guano for every inch of rain that makes its escape through the drains. This loss is greatest during winter and autumn, when there is little evaporation from the soil and no consumption of water by a growing crop. The best safeguard against such loss is in the absorbent power of the soil itself; but means may be adopted for diminishing the loss by a system of winter cropping. The growing crop not only absorbs and throws off into the atmosphere a portion of the rainfall, thus lessening the drainage, but it arrests the vagrant nitrogen, and stores it up in its roots, to be made use of by itself or by another crop the

following spring; and if the crop grown be a deep-rooted one, the advantage will be all the greater, as it will then bring nitrogen from the subsoil to the surface.

Alleged Over-draining.—The opinion is often expressed, even by practical men, that it is possible to lay land too dry by means of underground drains; and numerous examples of grass lands so injured have been cited. The effect of drainage upon grass lands is of course to bring about a change in the herbage, the water grasses and sedges common to wet land giving place to the grasses proper to dry land; but it will generally be found that, where any diminution in the produce of the land has followed drainage, it is only of a temporary character, and has probably resulted from a period of drought occurring during the change of herbage, just after the water grasses had died out and before the grasses proper to dry land have had time to establish themselves. If rain fell throughout this period of change the result would show to the advantage of drainage, just as it invariably does on grass lands which have been drained for any length of time, and on arable lands. The idea that land can be made too dry by any number of drains need not be entertained. That it is possible to make the depth of the drains beyond the capillary powers of the soil is true enough; but beyond this it is impossible to over-drain land. "The extent to which a soil can be made dry is dependent not merely on the drainage, but also to a very great extent upon its power of retaining water, in regard to which different soils vary within very wide limits. In order to illustrate this point, let us suppose a very fine sieve to be filled with a dry soil, and water to be poured upon it. The water of course will trickle

through the soil, and the greater part escape by the meshes of the sieve; but a certain quantity, dependent on the texture of the soil, will always be retained within its pores by capillary attraction. The former will represent that portion of water which flows off by the drains, while the latter will never enter them at all, and can only be got rid of by evaporation."

Need of Drainage.—There is very little land that is not too wet in rainy weather, and too dry in droughts; and drainage, as already explained, is a remedy against the last-mentioned evil as well as against the first. Notwithstanding all the drainage work of bygone years, the undrained wet land in Great Britain is probably not less than 25,000,000 acres. And it is too true that much of the drainage already done has been broken up by the abnormally wet seasons which have recently prevailed.

"It is lamentable," says the *Field*, "to note the effect of wet seasons on the permanency of drains, and this is especially true of those localities where the surface is flat, and where the land is affected by backwater, owing to floods. We have the misfortune to be intimately acquainted with such a district, where the land is above flood level, but where the drainage is often blocked for days, and sometimes weeks. The result is gradual blocking of the pipes from sediment. It is easy to understand how this occurs. The water backs up the drain and rises in the soil, which, having been disturbed in the making of the drains, is even more liable to be carried down with the retreating waters than the undisturbed land. Well, the flood ebbs often rapidly, the water sinks into the drain, and carries with it fine material, which is deposited. Varying according to the fineness of the soil, this process of blocking is a certain

result of backwater; and we have known drains that were most carefully laid rendered useless in a few years from this cause alone. It usually happens that the soil in flat districts is more or less derived from drift materials, and the particles of such soil are often so fine that they will penetrate through the joints of the pipes, however carefully laid, and despite all precautions that can be taken. One of the lessons of recent years most absolutely demonstrated is the temporary nature of drainage works, quite upsetting all our calculations. There are of course special cases, and great differences as to the limit of durability. Thus, we know of drains in peaty soils which require dragging out, as it is called, every three or four years, in order to remove a deposit of oxide of iron, locally known as 'red rag'; and we find drains in upland districts where the fall is considerable, which appear as perfect now as when they were put in twenty years since. In low land, and especially when the soil is composed of fine materials, it often happens that 2-in. pipes will require to be re-laid after periods ranging from ten to twenty years; and, even if not entirely renewed, they are subject to constant repairs."

Causes of Wetness.—Soils may be wet and in want of drainage from various causes. The most frequent cause is rain-water falling directly upon the soil in too great quantity, and finding no sufficient escape through subjacent porous strata. Sometimes it is water of pressure, or "soke," as it is termed in the Fens, which is simply rain-water that has fallen upon neighbouring higher lands and filtrated downwards till it burst out in a diffused manner on the surface of porous soils at a lower level. In other cases, springs are the cause of wetness. Certain lands, also, are subject to be over-

flowed and in need of drainage when rivers or tides rise sufficiently to bring water upon them.

Some lands are liable to suffer by one of these causes, and some by all of them; and to drain with advantage it is necessary to know how much of the surplus water is due to each of these causes.

Reference to geological formation must not, of course, be forgotten; for in carrying out the practical work of drainage very much of its success will be found to depend on a proper knowledge of the various strata, and their relative degrees of capacity for admitting or rejecting water. Some data on these points is given in the sixth chapter.

CHAPTER II.

METHODS OF UNDER-DRAINING.

Stone Drains.—Before drain pipes came into use, stones, gathered off the fields, were the common material of which drains were formed. Mr. Smith, of Deanston, even preferred stones to pipes, and he recommended that for this purpose the stones should be

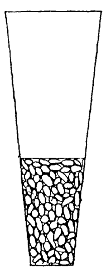


Fig. 1.

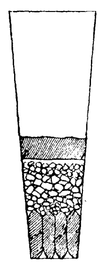


Fig. 2.

broken small enough to pass through a ring $2\frac{1}{2}$ inches in diameter. From 9 inches to a foot in depth of stone was the quantity commonly put in. Some, however, filled the drains half-way with stones; others set a flat stone with its foot against one side and its top leaning against the opposite side; and others, again,

adopted the different modes of construction shown in Figs. 1 to 6.

The use of stones as draining material is now, however, only justified where the land to be drained

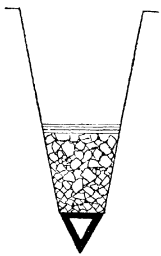


Fig. 3.

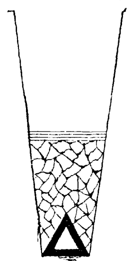


Fig. 4.

abounds in them, and no other use can be made of them. To make a good stone drain requires twice as much excavation, and involves twice as much labour, as is necessarily expended in tile-draining, and

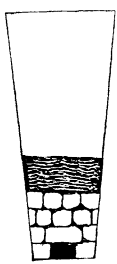


Fig. 5.

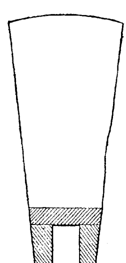


Fig. 6.

it is neither so effective nor so durable. In sandy and loose soils the stone channels are apt to get silted up by the water carrying fine particles of earth and sand down amongst the stones. Of course where it becomes

a question of carrying stones upon the field to be drained, nobody would now think of putting in a single rod of stone drain.

Pole and Fagot Drains.—Prior to the introduction of drain tiles and pipes, various other kinds of material were used instead of stones, where the latter were not available. Sometimes a number of larch or other poles were put in to form a conduit, as in Fig. 7. Bush fagots were also employed for the same purpose, and even hedge cuttings and ropes of straw were at times used in the formation of covered drains.

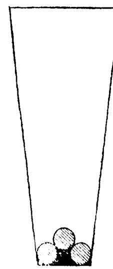


Fig. 7.

The Drain Pipe.—These are a few of the chief devices used in the early days of draining land. The invention of the drain pipe gave an immense stimulus to thorough draining, and thousands of acres of wet land, which previously had to be summer-fallowed, were laid sufficiently dry for turnip cultivation and sheep husbandry. A cart-load of pipes went a hundred times as far as a cart-load of stones; and as the pipes were of small diameter, comparatively little excavation was needed in putting them in.

The Horse-Shoe Tile.—The drain pipe itself has undergone various modifications. In its earliest form, the pipe or tile was made singly, and by hand. The

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

clay was rolled out, and then pressed over a block into the shape of a horse-shoe; and in using these horse-shoe tiles it was only deemed necessary to lay them on

a hard bottom of clay. It was soon found, however, that this was not enough. The run of the water wore the bottom of the drain and softened the clay, till the tiles were either displaced altogether or would sink into the bottom, and make the drain useless. The next improvement was to make the horse-shoe tile with feet, as in Fig. 9, in order to prevent it sinking into the earth or clay on which it rested. An obvious improvement on this, however, was to set the horse-shoe tile upon a flat sole, a little wider than the tile itself, as in Fig. 10. When placed in position the possibility of the tile sinking into the earth was overcome, and, at the same time, a solid run was provided for the water which flowed through the drain.

The cylindrical Drain Pipe.—The sole and tile was in turn superseded by the machine-made pipe, in which the horse-shoe form, as in Fig. 11, was at first closely adhered to, but this has now been entirely superseded by the cylindrical pipe shown in Fig. 12, which possesses many advantages. It forms a complete conduit in itself, it is stronger than any other form of pipe, its extreme lightness makes it very easy of transport, and owing to its small diameter a less quantity of earth need be excavated in digging a drain for a cylindrical pipe, at a given depth, than for any other drain material.

Fig. 12.

Pipe Collars.—Collars were for some time very generally used along with the cylindrical pipes, from an impression that they gave greater efficiency and permanency to the drain. The collars were short pieces of pipe just wide enough in the bore to admit the ends of the small pipes forming the drain, the

object being to cover the junctions of these pipes, and to prevent them moving out of position after being laid. Fig. 13 shows two drain pipes connected by means of a collar. The collars have now very generally gone out of use, the prevailing opinion being that they are an unnecessary expense on all clean-cutting and firm-bottomed soils. If a solid foundation for the pipes is unattainable, as in deep peat-mosses or the

Fig. 13.

like, where a certain amount of subsidence is sure to take place after the drains are finished—or if the pipes are liable to silt up from the nature of the material in which they are laid—the use of collars may still be advisable at times, but in the great majority of cases they can very well and safely be dispensed with.

How Water enters the Pipes.—The question, "How does water enter a drain pipe when it is laid three or four feet deep in the soil?" is one often asked by beginners. From experiments which were carefully carried out by Mr. Josiah Parkes, in order to determine this point, it was found that under a pressure of 4 feet of soil, the absorbent power of various pipes formed of various clays was equal to the passing of about $\frac{1}{500}$th part of the quantity of water which enters the conduit through the crevice existing between each pair of pipes. By so much, therefore, the porous nature of the pipe material is useful; but, practically, this influence is so small that we may regard the whole of the water as entering at the joints. And not only does the bulk of the water enter the pipes at the joints, but the greater portion of it enters the drain pipes from below.

In all soils requiring drainage there exists a water-table or level of supersaturation, and in a well-drained soil this level corresponds with the level of the drain pipes. When rain falls on the surface the water finds its way downwards till it reaches this water-table. It then begins to rise, and if the drains are sufficiently active the pipes will carry off this rise of water as fast as it enters them from below. If the water rises above the level of supersaturation faster than the drain can take it off, then of course the pipes become completely swamped, as it were, and the water enters at every part of the joints. When the rain has ceased to fall, however, the continued action of the drain will soon suffice to again reduce the water of supersaturation to its proper level; water will even cease to flow from the drains until more rain falls, and then the same thing will go on as before, the height to which the free subjacent water rises being wholly dependent on the activity of the drain, and the sufficiency of the pipe to carry off the water from it in a given time.

That the water will be freely admitted to the pipes at the joints is easily shown. With 2-inch pipes, when laid as close end to end as possible, the opening between two of them is usually not less than $\frac{1}{10}$th of an inch on the whole circumference. This makes six-tenths of a square inch opening for the entrance of water at each joint. In the length of a drain between any two points, say 100 yards distance, with pipes 12 inches long, there will be 300 joints or openings, each six-tenths of a square inch in area, or a total area of 180 square inches for admitting water to the drain. The area of the outlet from a 2-inch pipe is, however, only about 3 inches, so that the inlet area is nearly sixty times greater than the outlet area.

Manufacture of Drain Pipes.—In all drainage works of any considerable extent, it will pay to make the pipes on the ground, if clay at all fitted for the purpose is obtainable. There is nothing more suitable than ordinary brick clay; and by employing machinery in their manufacture, drain pipes can now be produced very rapidly and cheaply.

There are various machines used in this work, but they all operate on the same principle. This consists in squeezing a continuous length of soft plastic clay through a ring-shaped orifice, the centre of which is occupied by a core or mandrel of the size of the hollow part of the pipe; another arrangement of the machine being to cut the pipes to the proper lengths as they pass through, and by means of a travelling table to carry them forward to be removed to the sheds, where they are dried previous to being burned in the kilns.

Some of the machines only work the clay after it has been prepared in a pug-mill; others consist of a pug-mill and pipe-maker combined. The uncombined machines cost from £20 upwards, according to size, and are capable of turning out, by man-power, from 200 2-inch pipes per hour, and upwards, or with one-horse power from 3,000 to 5,000 pipes per day. The pug-mill costs about £10 extra.

One of the best machines known to us is that made by the Boness' Foundry Company. Two sizes of this machine are sent out. They are of the combined kind, and prepare the clay and produce the pipes at one operation. Their peculiarity is in the screening compartment, where the clay is entirely freed from stones and all substances which would cause bad pipes to come from the dies, and from which all such refuse is ejected. The smaller one can be easily driven by 4-horse power,

is worked by one man and three boys, and is capable of putting out of good clay 7,000 to 9,000 2-inch pipes daily. It costs, exclusive of driving power and belting, £70. The larger-sized one costs £100, can be driven by 5- or 6-horse power, is worked by two men and three boys, and turns out from 12,000 to 15,000 2-inch pipes daily.

A tilery, including a kiln capable of burning, say, 20,000 2-inch pipes, and drying sheds for the same, can be erected at a cost not exceeding £60; and with coal at 18*s.* per ton, the expense of manufacturing the pipes is from 15*s.* to 18*s.* per thousand. The quantity of coal used varies, as some clays require more burning than others; but on an average, perhaps, 2½ cwt. of coal will burn 1,000 2-inch pipes. The pipes are usually cut off the machine at 15 inches in length. In the processes of drying and burning, however, they shrink to 13 or 14 inches. (See Appendix, 10.)

Cost of Pipes.—The selling price of drain pipes varies greatly throughout the country, and in much the same ratio as does the price of coal. Appended are two price lists for the present year.

SELLING PRICES OF DRAIN PIPES OF VARIOUS SIZES AT THE KILN.

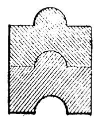
Inches diameter.	Gloucestershire.	Banffshire.
	£ s. d.	£ s. d.
2	1 5 0 per 1,000	1 9 0 per 1,000
2½	1 15 0 ,,	1 19 0 ,,
3	2 5 0 ,,	2 10 0 ,,
4	3 0 0 ,,	3 15 0 ,,
5	4 5 0 ,,	5 5 0 ,,
6	7 10 0 ,,	8 15 0 ,,
8	—	0 0 9 each
9	—	0 1 0 ,,
10	—	0 1 2 ,,
12	—	0 1 6 ,,
14	—	0 1 10 ,,

It is not too much to say that the pipes can be manufactured on the field at from one-half to one-third of the above cost.

Drain pipes, if well made and properly burnt, should be entirely free of warps and nodules; and if gently knocked, one against another, should give out a clear musical sound.

Peat Tiles.—Conduits formed of dried peat are sometimes used in draining peat-mosses and bogs, where there is always a superabundance of this material. These tiles are formed in half-sections, as shown in Figs. 14 and 15, and are cut with a spade similar to that represented in Fig. 16. They are fairly durable in soils of the class mentioned, and have certainly the merit of cheapness, as they are dried in the sun, the only cost being that of cutting and handling them.

Fig. 14.



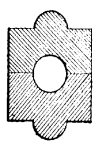


Fig. 15.

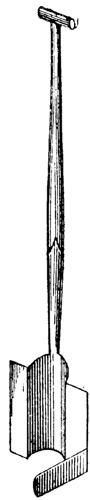


Fig. 16.

Wedge and Shoulder Drains.—Underground draining is also occasionally practised without the use of any drain material; and that in various ways. The most simple forms of these drains are what are known as the wedge-drain and the shoulder-drain. They are mere channels in the subsoil, formed by the bottoms of the drains being cut very narrow, and the upturned turf or grassy spit from the surface made to rest on the top of the wedge or shoulder, thus leaving a vacant space in the bottom of the drain, as shown in Figs. 17 and 18. These drains are less durable than

the peat-tile drains, and like them are only adapted for old pasture lands, where they are entirely beyond the risk of disturbance by tillage operations.

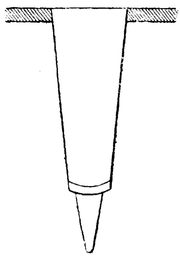


Fig. 17.

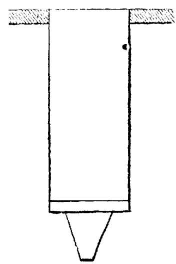


Fig. 18.

Draining Ploughs.—The mole-plough affords, perhaps, the cheapest means of under-draining without the use of any foreign material. The strong coulter of this plough carries on the back of its point a mole or plug, which leaves an open channel behind it, as it is drawn through the soil. The channels thus made in the land deliver into properly-constructed main drains with pipes of sufficient size. The implement can be made to work at any moderate depth, and either by horse or steam power; but it can only be used satisfactorily on homogeneous clays, or free loams, and is better suited to grass lands than to lands under tillage.

A recent correspondent of the *Agricultural Gazette*, who advocates mole-plough draining, may be quoted as to the cost of this method.

"Cost of Draining by Mole-plough.

"July 11th, 1881.

"Sir,—I am glad to find that the old-fashioned excellent practice of draining by mole-plough, with the use

generally of steam-power instead of horses, has been revived with energy. As the following figures are facts, you may like to publish them. They represent the cost of draining a field (21 ac. 2 rd. 24 pl.) in Hoofield with mole-plough, and pipes in main drains:—

	£	s.	d.
Mole ploughing 1,328 rds. at 2½d. per rd. . . .	13	16	8
Cutting main drains	3	1	0
Pipes	5	2	6
Labour, coals, &c.	3	0	0
	£25	0	2

"The mole drains were made 8 yards apart. The cost per acre comes out at 23*s.* 1*d.* As the field may have been favourable for the work, the average may be put at 25*s.* an acre. This is certainly a very inexpensive method of laying the land perfectly dry to a depth quite sufficient for all the purposes of practical farming. The time has again come for economy. . . . Mole-plough draining will admit of at least 12-inch ploughing, &c.

"TOP SPIT."

Fowler's draining plough, which gained the Royal Agricultural Society's medal at Lincoln in 1854, where it was first worked by steam-power, may be used either as a mole-plough or to put in pipes. In the latter case it aims at making a complete pipe drain at a single operation, the drain pipes being strung on a rope, and rope and pipes together being drawn through the soil, behind the mole fixed on the point of the coulter. It may be worked to a depth of 3½ feet in suitable soils: and either by horse or steam power. It is said that the work done by this plough at the Lincoln meeting in 1854 is still giving entire satisfaction. Fig. 19 shows the improved form of Fowler's mole-plough.

But after all is said and done, draining by means of

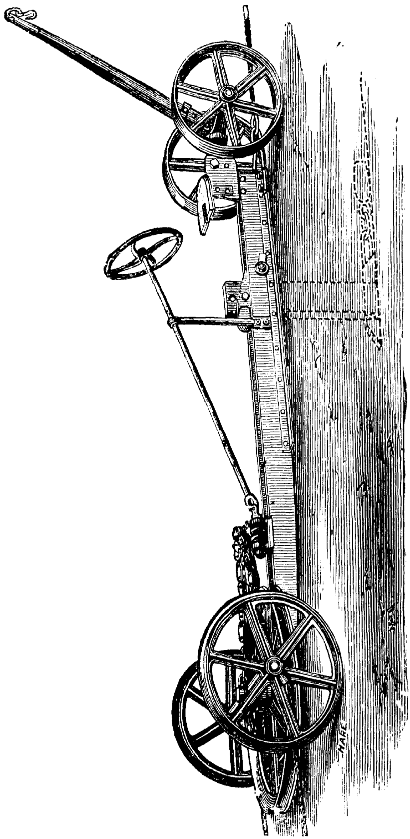


Fig. 19.

the mole-plough, even where it puts in no pipes, can only be practised to a very limited extent on the soils of this country.

Draining Machines.—The latest and perhaps the most ingenious implement of this kind was exhibited at the Derby Show in 1881, by Messrs. Robson and Herdman, the patentees. By the use of this machine, of which Fig. 20 is a side illustration, the complete process of land draining is automatically accomplished. The drain is excavated by a series of revolving buckets cutting to the required depth and fall; the drain pipes

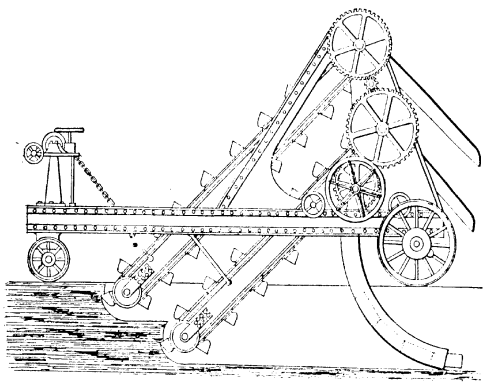


Fig. 20.

being laid by the arrangement shown in the drawing, and the earth returned to its position by suitable shoots, the subsoil being conveyed to the bottom of the drain. This machine is driven by a wire rope like a steam-plough or cultivator, and requires no more skilled attendance. Its cost (£390) appears to us simply prohibitive to its use; but it has never been fairly tried; and the inventors, we believe, have for some time past been engaged in working out some new idea in connection with the machine. Since 1881, the

Royal Agricultural Society has annually offered a gold medal for the best draining machine, but the medal is still unawarded. As Mr. Pidgeon, in his recent paper before the Society of Arts, has aptly pointed out, "several difficulties attend the problem of automatic pipe-laying. It is not easy to provide for a proper and equable fall; it is difficult to place the pipes accurately in contact end to end; and it is a question how turning at the headlands is to be accomplished."

CHAPTER III.

ARRANGEMENT OF DRAINS.

Determining the Outfall.—In proceeding to drain a field, the first thing to do is to decide on the point of outfall. Where the surface is undulating there is seldom any difficulty about this; but on low, flat lands it is often impossible to determine whether the ground has any fall or not until the levelling instrument is brought out. The number of outlets required will depend on the size of the field, and on the configuration of the land. If the land does not slope in more than one direction, and if the field is not of large extent, one outlet will probably be enough. Otherwise, however, it may happen that several outlets are required. If all the drains can be led in one direction, a single outlet may suffice for a field of 12 or 15 acres; in this area, however, there ought to be three or four main drains, all converging on one point. If the land has little inclination, there will be great advantage in concentrating the whole of the drainage on one outlet, and care should likewise be taken to run the main drains in straight lines towards the point of discharge. Where the inclination is greater, and the field to be drained is larger, a second or even a third outlet may be advisable, in order to shorten the lengths of the main drains.

Laying out the Main Drains.—The next step is to lay out the main drain or drains in the best direction for receiving the minor drains. This will always be along the lowest line of ascent from the point of outfall.

Arrangement of Minor Drains.—In the arrangement of the minor drains, the aim should be to lay the land dry with the smallest possible number of drains. Not a rod of drain should be cut that is not going to be beneficial. The causes which render the soil wet must first be considered. When these are known and understood, it will be easy to decide upon the best means of providing a remedy. But in this consideration the sectional strata of the district must be taken into account, as well as the contour of the surface, and the texture of the super and subsoils.

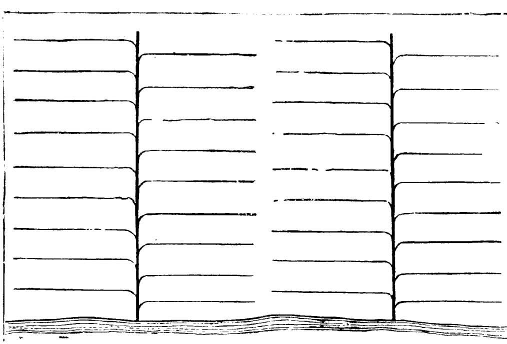


Fig. 21.

If the surface of the ground is level, and the structure of the soil uniform, the drains may be arranged at regular intervals apart (Fig. 21), with feeders at right

angles to the mains, and the necessary slope must be gained by cutting (Fig. 22) deeper towards the outfall.

An undulating surface requires the mains to be placed at the lowest levels, and the minor drains

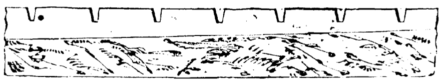


Fig. 22.

should run into them in the direction of the inclination of the ground (Fig. 23). When the surface inclines, there will be generally sufficient fall for dis-

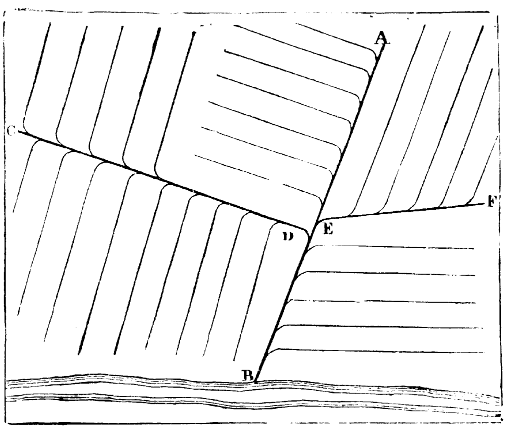


Fig. 23.

charge if the drains are cut throughout to a uniform depth (Fig. 24).

If the sectional strata consist of soils of various retentive powers, their relative positions, both in plan and in section, must be regarded in the arrangement

of the drains. It is want of attention to this point which is the true source of so many fruitless attempts at successful land-drainage. Instead, of following

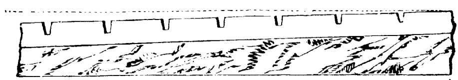


Fig. 24.

ready-made rules for fixing the proportionate depths and distances of drains in light and heavy soils, we must determine these points by reference to the thickness and order of the substrata, no less than by the character and texture of the supersoil.

Direction of Drains.—With the exception of the main drains, which must conform to the contour of the land and the point of outfall, all drains should be directed against the hill, or run in the direction of the greatest slope, and not made to cut it diagonally. By cutting across the slope a drain will undoubtedly intercept the water from the land above it, but it will do nothing towards relieving the wetness of the land below it. On the other hand, by cutting against the hill the land is not only drained on both sides, but a drain so applied will drain a soil deeper than the drain itself, as water lying above a given point will be drained to a depth the difference of the fall from the point in question in a direction up the level of the drain. Further, it is obvious that a drain laid on across the slope of greatest inclination, or diagonally to it, will not empty itself so soon as one which follows the direct line of greatest inclination. Where the flow is sluggish it even happens at times, with the drains laid on across the slope, that some of the water finds its way through the sides of the drains before it reaches the point of

outlet, and thus, instead of serving to drain, helps to keep the land below it wet. So that while a drain cut down the slope will receive the water from the sides, the top, and the bottom, a drain across the slope will only receive the water at the upper side of it.

Yet there can be no hard or fast rule in this. An exception is generally made in draining old pastures lying in high ridges, that have, perhaps, for generations determined the direction of the water, when these run obliquely to the ascent. This is entirely to ignore the fact that the forming of land into ridges and furrows was the original mode of surface drainage, and that if under-drainage is properly carried out, there can be no need of surface furrows. Unfortunately, a large portion of the arable surface of England still partakes of the ridge and furrow form; even on strong clay arable lands, however, the ridges and furrows are mostly disregarded, particularly if they are of irregular width.

There is sound practice as well as sound theory indicated in Mr. Bailey Denton's lines:

> "When land is drained no furrows keep,
> But lay it flat and plough it deep."

"I have seen many clay-land farms that have not been rendered dry by draining," says Mr. Denton, "because in order to develop the draining those lands require an after treatment,"—deep cultivation and laying them flat where they have been in ridges—"which they have not received. There are many farmers who believe that if their land is drained they have nothing to do to help the drains. There is no greater mistake. Deep cultivation on land moderately drained very materially assists to rid the land of water. The more

you stir the soil the more you assist in drainage, and the fewer drains you require." On under-drained pasture land nature performs this work for herself. Every shower that falls makes both surface and subsoil more porous, carrying air and rain together down to the drains.

Again, in any case it will be useless to drain against the dip of the strata. It may also sometimes occur that the existence of a spring between two parallel drains may necessitate its being led into one of them by means of a side drain, although, if the parallel drains are not over distant, the water in such cases will generally find its own way. The extreme mobility of water, and its tendency to force its way along by its own gravity, wherever the pores of the soil are open to the atmosphere, is well known to every one. If a pipe drain be laid down in a dry soil, the channel is immediately filled with air, but when rain falls, and the soil becomes saturated to the level of the drain, the water in the soil, by reason of its greater weight, occupies the place of the air in the drain. The water which is nearest to the drain is first drawn off, then that next to it immediately takes the empty place, and so on and on, the last pushing and driving the first beyond any limits which we can affix to it.

Inclination.—The rate of fall which can be obtained according to the surface levels of the district is not only important as regards the discharge of the water from the pipes, but it will occasionally have an influence in regulating the depth of the drains. Theoretically, water will flow if there be but the smallest possible deviation from a horizontal line; but in practice this is not sufficient, for it implies a perfectly smooth and level bed, a condition which does

not exactly exist in land drains. A fall of one in two hundred will afford good drainage, but in the stiffer class of soils an inclination of one, two, three, or more in a hundred is preferable, if obtainable. The water should not pass too quickly through the soil before it has time to deposit its nutritive ingredients; but neither should it be allowed to stagnate, as it will do if the drains are deeper than it can readily permeate, or if the fall is insufficient to induce a free discharge. On very porous soils a smaller inclination will suffice than is necessary with a soil where percolation is not so rapid. When the drains are sufficiently active they will not allow the water to stand on the surface longer than a few hours after heavy rains. Stone drains require more fall than tile drains, as the friction to be overcome by the water is greater in the former.

Length of Drains.—Long drains, as a rule, are more effective than short ones. This is seen to perfection on the wet level lands which are sometimes met with, where it is very difficult to get drains to run, unless such a quantity of water is collected in them as forces a current by its own gravity. In such places long drains are an advantage, as the increased quantity of water which they collect causes a constant run, which keeps them clear and free of obstructions. But it is one of those matters of detail which must be decided according to the circumstances of the case. Some advise that the length of a drain should not exceed 300 yards, and that where there are springs in its course it should not exceed 200 yards. Main drains, undoubtedly, should be made shorter rather than longer, if there is any choice, because the longer the main, generally, the greater the number of feeders

led into it; and to lead the drainage of a large tract of wet land all into one main drain is very often to endanger the safety of the whole, if an obstruction should occur in the main, or it should prove inadequate to carry off the water.

CHAPTER IV.

DEPTH AND FREQUENCY OF DRAINS.

Depth of Drains.—"The circumstances affecting the proper depth and distance of drains are very numerous. Deep drains are longer in beginning to flow, but if the soil is porous, they will carry off the surface water after heavy rains sooner than shallow drains. They also drain a greater bulk of the soil, and allow the water time to deposit the particles of mould and manure which it carries in from the surface of the ground.

"On an open soil which the water penetrates freely, the action of the drains will extend to a considerable distance, if the depth is made proportionate; but on stiff, compact soils, percolation will be greatly hindered, and therefore the action of the drains will extend a less distance than on free and open ground, where the water finds a ready escape. No amount of depth will compensate for excessive distance on a compact soil, because the material either resists the passage of the water altogether, or the removal is so slow that the drainage is worthless. It is also evident that drains may be laid too deep, for the same causes which hinder the lateral course of the water are obstructive to its vertical descent in the soil.

"If the upper bed is retentive, and of such depth

that the drains cannot be cut completely through it, the best system to adopt will be shallow drains at close intervals; and, on the contrary, a pervious material should have deeper drains at wider intervals.

"If a comparatively thin bed of clay rests upon a porous substratum, the drains should be cut into the latter, or through it, according to its depth; and they must in any case be laid at small intervals.

"When the case occurs, as it sometimes does, that a free supersoil about three feet in depth overlies a comparatively thin bed of clay, it is often advisable to limit the depth of the drains to that of the porous bed. By penetrating the clay the land would be better drained, but in doing so there is a risk of exposing springs, if they exist below the clay.

"The requirements of vegetation must also be considered in determining the proper depths of drains. The depth to which the rootlets of the plants penetrate may afford some indication of how far the free subjacent water should be retained below the surface. It is often alleged that in dry summers, grass land especially is subject to great injury, owing to the depth of the drains below the rootlets being beyond the capillary power of the soil. There is, however, strong evidence that the roots of all our cultivated crops, grasses included, do descend and appropriate the soil to as great a depth as they are permitted; and it should not be forgotten that every inch of additional drainage, or every inch of additional depth cultivated, is a gain of 100 tons of active soil per acre."

In reference to this part of our subject, Mr. J. Bailey Denton says:—

"I published recently some very curious illustrations

* "Soil of the Farm." By John Scott and J. C. Morton.

of the dislike plants exhibit for stagnant water in the soil. They afforded proof that directly the roots reach the standing-water level, they ceased to penetrate farther. I have evidence now before me, that the roots of the wheat plant, the mangold wurzel, the cabbage, and the white turnip, frequently descend into the soil to the depth of 3 feet. I have myself traced the roots of wheat 9 feet deep. I have discovered the roots of perennial grasses in drains 4 feet deep; and I may refer to Mr. Mercer, of Newton, in Lancashire, who has traced the root of rye-grass running for many feet along a small pipe drain, after descending 4 feet through the soil. Mr. Hetley, of Orton, assures me that he discovered the roots of mangolds in a recently-made drain 5 feet deep; and the late Sir John Conroy had many newly-made drains, 4 feet deep, stopped by the roots of the same plant."

For purposes of cultivation, the drains should never be laid at a less depth than 3 feet from the surface of the ground. Even with steam ploughing and subsoiling, the depth of, say, a 2½-foot drain will not ordinarily be reached; but it is evident that drains may be completely destroyed by the operations of tillage, without the drain pipes being actually touched or disturbed. In most soils, shallow drains become rapidly choked by being filled up with fine particles washed down through the openings occasioned by tillage and other surface influences. This is especially the case on fine sands and alluvial deposits, where the silt rapidly penetrates to the depth of a shallow drain. Deep drains for these reasons are more secure and remain longer efficient.

Solar influence, also, is not without its effect on the proper depth of drains. Clay lands with a southern

slope will require drains at a greater depth than lands with a northern aspect: and, likewise, lands of a southern latitude than those of a northern.

Lastly, as has been already seen, the rate of fall obtainable according to the surface levels of the district has its effect in determining the depth of drains. Where the outfall is deficient, as in the case of most low-lying lands, the top ends of the drains can rarely be made so deep as the lower ends; and the same rule has to be observed wherever the surface is so flat that there is no other means of giving the drains a proper fall.

Recent Practice in Draining.—Whatever may be said in favour of deep drains as against shallower ones, there can be little doubt that closer draining is now being practised than was formerly believed necessary by the advocates of deep drains, and the inference is that they are at the same time draining shallower. On this head some curious and important revelations were made by Mr. Bailey Denton in his evidence before the Royal Agricultural Commission. Some of Mr. Denton's answers to questions relating to drainage are of so much consequence that I give them in full here.

At page 169 of Minutes of Evidence, he is reported to have said: "There is no doubt but that the rules prescribed by the Enclosure Commissioners, with regard to the necessary depth of parallel drains in clay soil, and the distance between them, have not been fully justified with free soils and irregular surfaces.

"It is found that no rule whatever will apply with clay and homogeneous soils. . . . The generally adopted parallel system, based on the theory propounded by the late Mr. Josiah Parkes, that the deeper the drains the wider may be the intervals between them,

does not hold its ground. When obliged, by the rules laid down by the Enclosure Commissioners, to conform to the depth of four feet, landowners were encouraged by the Parkes' theory to lessen the frequency of the drains in order to keep down the cost. The result was that the distance was extended beyond the limit of reciprocal action, and it has now been found that the full effect aimed at has not been secured. Instead, however, of attributing unsatisfactory results to the real cause—*i.e.* excessive distance between the drains—they have been attributed to excessive depths, and the principle of deep drainage, which is sound in itself, has thereby lost ground. With the cost of manual labour increasing in this country, without the returns of farming keeping pace with the advance, it has become positively necessary, if clay lands are to be drained at all, that a compromise should take place. A width of 24 ft. is taking the place of 36 ft., and a minimum depth of 3 ft. that of the universal 4 ft." Again, at page 223, he goes on to say: "I certainly am bound to confess if I had some drainage that I have executed to do again, I should drain it differently; but I do not take to myself any blame for that. It was a law, a rule of the Enclosure Commissioners, to drain 4 ft. and nothing under. That required a certain width, a certain distance between the drains, to bring the cost to a reasonable amount; and land was drained 30, 33, and 36 ft. apart, which, if I were to drain again, I should not certainly exceed 27 ft. in interval; 21, and 24, and 27 ft. would be the distances I would now adopt in place of 30, 33, and 36 ft. The Commissioners are now, I believe, acting on that view, and they no longer require 4 ft., except in cases where their inspector considers 4 ft. the best depth to drain."

Distance between Drains.—Practice seems to say that the distance between drains on strong clays may be from four to six times the depth, on strong loams six to eight times the depth, and on light soils eight to ten times the depth.

It is easy to discover the origin of the rules for distances by looking back to that of parallel drainage. Prior to the practice of under-drainage, strong and wet lands were rendered capable of tillage by being ploughed up in the waving shape termed "ridge and furrow," the bottom of the furrow forming the drain for the ridge. In consequence, however, of the crops perishing in and by the sides of the furrows, the water was drawn off from them by having shallower drains below each, and kept open by straw or brushwood. This was termed furrow, or thorough draining. "It is thus that the distances of the furrows from each other indicate the distances of the drains in any particular district. And the distances now most commonly in use, in different districts and on different sorts of soils, have all reference to a width of ridges that either formerly was, or now is, in use in those districts. Throughout the country the statements of the number of feet from drain to drain is, in almost every instance, when reduced to inches, divisible by 18, that being the width of ground moved at a single bout of ordinary ploughing."

Gradual Drainage of Boggy Land.—The perfect drainage of deep and wet boggy land is a gradual process, requiring some time to reach the proper depth. The drains in this case should be cut at first only as deep as the sides will stand, and gradually deepened as the land subsides, taking care to keep the open trenches

[1] Mr. Spooner.

well cleared out. When the land has become sufficiently consolidated, the usual pipe drains may be put in, but they should be laid rather beyond the depth which would be thought necessary in a firmer soil of the same nature. If the moss will not carry the ordinary pipes, it will be advantageous to use collars with them, in order to prevent their displacement.

Draining Peat Mosses.—Peat or vegetable soils possess, in a very strong degree, the power of capillary attraction, and their porosity is also so great that if one portion of the peat be made dry the moisture contained in the other parts will rapidly distribute itself through it. In order, then, to drain a peat soil thoroughly, and to counteract the effects of capillarity, the drains must be laid deep, but they need not be so frequent as in less porous soils. A single ditch dug down to the bottom of the peat, or as near it as possible, will draw off a considerable quantity of the moisture, not merely from its immediate neighbourhood, but from the whole moss. Where the peat is of no great depth, and recumbent on a clay bottom, the drain should, if the outfall will admit of it, be cut through the peat into the clay, after the manner shown in Fig. 25. If this plan can be adopted it will have the effect not only of depriving the peat more completely of its moisture, but it has an additional advantage, inasmuch as the sides of the drain will stand better while it has to remain open.

Auger Holes.—Where springs which are fed from a higher level lie immediately below a clay substratum which exceeds the practicable depth of the drains, recourse may be had to tapping, by means of an auger hole, or vertical bore, in order to open a communication

to the drains, by which the contents of the springs will be carried off.

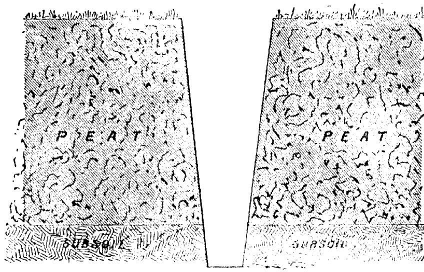


Fig. 25.

"Marshes, and even lakes, which occupy a bowl-shaped cavity, rendering drainage by the ordinary means impracticable, have been completely drained by boring through the impenetrable surface layer when it is not thick, and rests upon a porous substratum of sufficient depth to bear the water and carry it off from the surface. But this method must not be tried without due attention to the disposition of the sectional strata of the district, for if the porous soil is surcharged with water from a higher level the proposed cure will prove an aggravation of the existing evil. In that case the object may be attained by cutting a deep ditch or canal through the bank, on a level with the bottom of the lake." *

Swallow-holes and absorbing Wells.—There are extensive areas of land resting on a chalk subsoil where drainage, both natural and artificial, is carried on by means of what are known as "swallow-holes," or "dumb-wells." In all chalk formations "there are

* "Soil of the Farm."

large sand and gravel pockets, like inverted sugar cones, the origin of which is this. The rain water falls on the surface, and pure water being a powerful solvent of lime, dissolves it and filters down and is carried away in the springs. That goes on, and the gravel follows it down, and so we have these inverted cone and pipe deposits in the chalk in some instances of great depth, simply showing the solvent action of the water on the lime." In many districts where a clay soil overlies the chalk, by sinking a "swallow-hole" through the clay, down to the chalk, the drainage of the land is completely absorbed.

The best method of getting rid of springs will be suggested by surrounding circumstances. In few cases will it be necessary to do more than tap the spring and carry it off to the nearest drain or other outlet.

CHAPTER V.

THE DIGGING OF DRAINS.

Best Form of Drain.—In digging a drain it should be cut as narrow as possible. If the bottom is just wide enough to receive the pipes (Fig. 26) it is all that is necessary; moreover, when the pipes are thus accurately fitted in, the drain is more efficient, and, at the same time, more cheaply cut. Every spadeful of earth excavated beyond what is actually needful, in order to admit of the pipes being properly laid, is labour and money wasted.

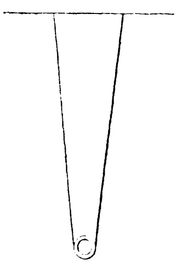


Fig. 26.

This accurate fitting in of the pipes is, with skill on the part of the workman, rendered quite practicable in the case of all soils tolerably free from stones, by the excellence of the draining tools that are now obtainable.

Marking out the Drain.—The drain should be staked and lined, and then edged, or marked out, on both sides by means of a common garden spade, such as shown in Fig. 27, which is also the best tool for removing the turf, or top spit. The middle and bottom spits are taken out by long tapering spades, similar to the Birmingham spades illustrated in Figs. 28, 29, and

30, each spade being followed by a corresponding-sized scoop to take up the loose earth. The scoops used are represented in Figs. 31, 32, and 33.

Digging.—In digging a 3-foot drain, after taking

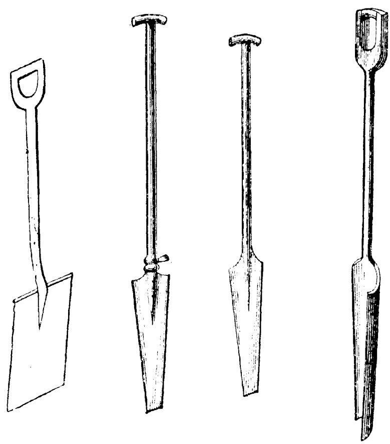


Fig. 27. Fig. 28. Fig. 29. Fig. 30.

off the top spit with the garden spade, only two of the long spades, as a rule, are used—one to take out the middle spit, another to take out the bottom one. In digging a 4-foot drain, however, there are generally three spits besides the top one, and in this case all the three Birmingham spades, or others, would in turn be called into use. The one which cuts the last spit (Fig. 30) is called the bottoming tool, and its introduction has effected a considerable saving in the cost of cutting drains.

Where the subsoil is hard, the pick has often to be used. In some soils, indeed, the pick has to be

employed in loosening every spadeful of earth before it can be thrown out. In such cases the long

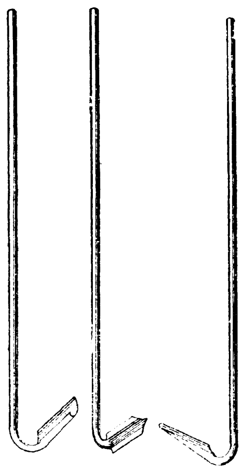


Fig. 31. Fig. 32. Fig. 33.

tapering spades are comparatively useless. Where picking is required, the drainer must stand in the bottom of the drain to get at his work, and this occasions a much wider cutting than in soft clays where the workman can stand above his work and send his long spade down 12 or even 18 inches lower. The cost of cutting drains in these hard or stony soils is of course considerably greater, both on account of the picking which is necessary, and by reason of the greater quantity of earth which has to be excavated. The picks, or pick-axes as they are sometimes termed, are usually made with a point at one end and a chisel or axe at the other (see Figs. 34, 35).

The digging should commence at the lower end, and proceed up the hill, thus allowing the water to run off and leave the drain dry digging. It is most

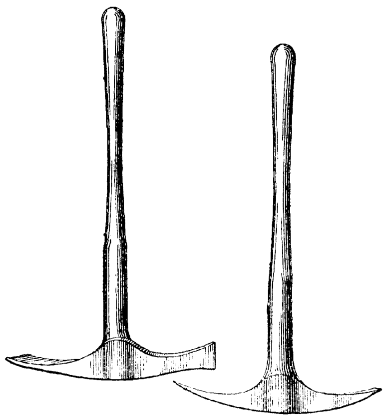


Fig. 34. Fig. 35.

important that the bottoms of the drains should be properly graduated. To ascertain this, various tests may be applied. One is to pour water into the drain at the upper end and mark any interruptions in its flow. In other cases the levelling staff is used. But for irregular surfaces the use of "boning rods" is to be recommended, though these serve only to show the evenness of the drain bottom, and not the amount of fall. Three "boning rods" are the fewest that can be used. Two of them are staves about 4 to 5 feet long, with cross-heads, and one of these is set up perpendicularly at each end of the drain. The third staff is considerably longer, with a movable cross-head, and is set up at the same height as the others; and when

held perpendicularly and moved up and down the drain between the two end staves it shows to a person looking across the cross-heads where the bottom of the drain is faulty.

Where the drains are deep and the sides apt to fall in, the earth should be first taken out the whole length of the drain and within a foot or so of the intended depth ; then the bottom spit can be taken out by one or more men according to the length of the drain, and the bottoming and laying of the pipes all completed in one day.

The Upton Draining Tool.—This implement, although it has certain advantages over the ordinary flat and curved spades, and has had its merits well described by Mr. Milward, has been much neglected. For deep draining in clay soils its use is certainly to be recommended, both for the ease with which a great depth is obtained at one thrust, and the small quantity of earth required to be excavated and filled in.

In using the flat or straight-edged spade, it will be found that the drainer inserts it thrice into the ground before he can remove the spit of earth, as is shown in Fig. 36. A thrust on each side separates the spit laterally, and the last thrust detaches it at the bottom. Great force would be required to tear the spit of earth from its place without previously detaching it at the sides. The curved tool is intended to obviate this necessity, but is not found to do so effectually in practice; the spit of earth, as is seen in Fig. 37, is still not completely separated at the sides, and must either be torn away or detached by side thrusts.

The inventor of the Upton draining tool thought that the resistance thus offered to an ordinary draining spade could be very materially diminished if the spit could

be entirely detached as the tool descended. He decided, therefore, on a tool with two sides united together at the back, so that its section would be like the letter V. Considering, also, that if spits in the form of equilateral prisms could be taken out, the drain would be most readily excavated, the angle between the sides was fixed at 60°—the angle of an equilateral triangle.

In using this tool, which is illustrated in Fig. 38, the

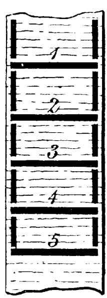


Fig. 36.

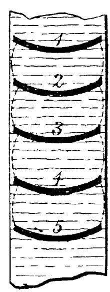


Fig. 37.

right side must be kept flat against the right side of the drain; and when this spit is withdrawn and the next thrust is made, the left side of the tool must be kept against the left side of the drain, and so on alternately.

Fig. 39 shows the manner of using the tool. The black line V shows the mark made on the surface by thrusting the tool into the ground; *h* indicates the position of the handle; the spits of earth marked out on the surface are numbered 1, 2, 3, 4, and 5, in the order in which they are removed. *A* is a piece of iron fixed as a rest for the foot in driving the tool into the ground.

In deep clay soils the success of this tool is very great. It is made of different sizes. The first and largest takes out a depth of about 18 inches; and longer but narrower tools are used for completing the dain to the required depth, the width at the bottom being only 3 or 4 inches. Some dexterity is required in keeping the tool properly along the side of the drain, also in withdrawing the spit which has been cut out; but the latter difficulty is easily overcome by inclining the spade a little instead of driving it straight down.

Fig. 38.

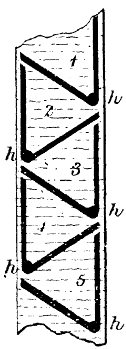


Fig. 39.

Opening Drains with the Plough.—The drain plough is sometimes used as an adjunct in opening drains; but it is more often heard of than seen. Mr. Wilson, however, has recorded his experience in the use of this implement, and the results may be given. The price of the plough, in full working order, he puts at £20; and the cost of using it for one day (including horses, men, and wear and tear, and interest on capital) at £3 12s. In one day's work the plough opened 1,800 lineal rods of drain 20 inches deep, 16 inches wide at the top, and 8 inches wide at the bottom, thus leaving room for men to follow with draining spades to the required depth. The cost of cutting is thus less than a halfpenny per lineal rod of drain; or, 2,333 cubic yards of earth are cut and thrown out at a cost of

4-10ths of a penny per cubic yard, which shows a considerable saving when compared with manual labour.

Quantity of Earth moved.—Mr. Denton, in his evidence before the Royal Agricultural Commission, declares that "The character of earthworks has not improved at all in the thirty years during which I have been connected with the General Land Drainage and Improvement Company. I find that with an expert hand and good tools, a 4-foot drain may be cut with a 13- or 14-inch opening at the surface, tapering down to 4 inches at the bottom, and that then the quantity of earth removed is reduced to a minimum; nevertheless, the same quantity of soil is still thrown out that used to be thirty years ago—double the amount that is necessary." This does not say much for our fine old English navvy!

The item of labour can easily be determined by referring it to the standard of the value of moving a solid yard of earth of any one description of hardness or tenacity.

Table of Earth-work.—The following table gives the number of cubic yards of earth in each rod of drains of various dimensions, and will show the economy of guarding against needless width in digging drains.

Depth of Drain.	Mean Width of Drains.											
	in. 7	in. 8	in. 9	in. 10	in. 11	in. 12	in. 13	in. 14	in. 15	in. 16	in. 17	in. 18
Feet.	Cubic Yards.											
2½	0·89	1·02	1·14	1·27	1·40	1·53	1·65	1·78	1·91	2·04	2·16	2·29
3	1·07	1·22	1·37	1·53	1·68	1·83	1·98	2·14	2·29	2·24	2·60	2·75
3½	1·25	1·42	1·60	1·78	1·96	2·14	2·32	2·49	2·67	2·85	3·03	3·21
4	1·42	1·63	1·83	2·04	2·24	2·44	2·65	2·85	3·05	3·26	3·46	3·66
5	1·78	2·03	2·29	2·54	2·80	3·05	3·31	3·56	3·82	4·07	4·33	4·58

Thus, if a 4-foot drain be cut 14 inches wide at top and 4 inches at bottom, the mean width will be 9 inches, and the quantity of earth excavated in cutting each rod will be 1·83 cubic yard; but if the same drain be cut 18 inches at top and 8 inches at bottom, the mean width will be 13 inches, and 2·65 cubic yards of earth will have to be removed in cutting each rod; so that if the digging of the drain costs 2*d.* per cubic yard of earth moved, the narrow drain will cost $3\frac{2}{3}$*d.* per rod, and the other nearly $5\frac{1}{3}$*d.* per rod, showing the cost to be almost doubled quite unnecessarily.

The same table will be found useful in helping to fix the relative prices of deep and shallow drains; but it must be recollected that the deeper drains will be increased in cost not only by reason of the greater quantity of earth which has to be moved, but also because of the increased labour of lifting the earth to the surface from a greater depth.

Supervision and Maintenance of Drainage Works.—As land drainage, if well done, is done for a lifetime, it is a work which should be closely and carefully superintended. If the pipes are once covered all defects are hidden until the drains are tested and found wanting—hence the importance of supervising the work as it proceeds. But the need of supervision does not end here. Mr. Bailey Denton rightly says that much of the discredit and unpopularity attending drainage at the present day, is due to the want of proper supervision *after the work is executed* to see that the pipes and outfalls are kept clear. And yet the charge of 2*d.* per acre in several instances has been found sufficient to secure the proper maintenance of outfalls.

Plans of Field Drains.—"Having perfected the

work," says Mr. Denton, "one thing still remains to be done. A plan or record of the lands drained and the position of the drains is necessary, and in order that such a record may be preserved for future generations it is desirable that a national office connected with the Tithe and Enclosure Commissions should be set apart for the purpose. . . . . The cost of planning the drains after execution need not exceed 6*d.* or 9*d.* per acre where a map of the lands already exists, and after we have spent £5 per acre in draining, does it not appear the very height of folly not to preserve a record of so expensive an object at a cost of 6*d.* per acre?"

CHAPTER VI.

SIZE OF DRAIN PIPES.

Influence of Length of Drain on Size of Pipe.—As regards the size of drain pipes it is very important that the capacity should be of ample proportion to the quantity of water they have to discharge. When the drains are of great length pipes of different diameter should be used, the larger-sized ones being placed at the end of discharge into the main drains. It is only in this way that the size of the pipe in every part of the drain can be proportioned to the greatest quantity of water which will flow through it. For example, if a drain is 500 yards long, and the distance between the drains is 8 yards, the pipe at the mouth must be able to discharge all the water drained from the 4,000 square yards of land, while at the middle or half-length of the drain the pipe will only require to convey the water from 2,000 square yards.

Level Ground requires larger Pipes than where the Inclination is greater.—It often occurs, too, that the lower part of the field is more level than the upper part, a circumstance which demands a larger-sized pipe, because the velocity is less while the discharge at this part of the drain is generally greater. Again, on lands nearly level, the diameter will require to be greater than on those of considerable inclination.

These are points of far greater consequence than is often imagined, for in very many cases the same size of pipe is used for all lengths of drains.

Construction of Pipe influences discharge.—The smaller the pipe and the less the amount of water to be discharged, the greater ought to be the care in having pipes of perfect construction. In some trials with drain pipes it was found that with pipes of the same diameter, exactitude of form was of more importance than smoothness of surface, that glass pipes of a wavy surface discharged less water than clay pipes of exact form. By passing pipes of common red clay under a second pressure, obtained by a machine at an extra expense of 1*s.* 6*d.* the 1,000, whilst the pipe was half dry, very superior exactitude of form was obtained; with the same diameter, an increased discharge of nearly one-fourth was effected in the same.

Influence of Rainfall.—Great caution is needed in coming to conclusions as to the amount of discharge with a given rainfall. In some cases the drains begin to flow nearly as soon as the rain begins to fall, and cease to run immediately on its becoming fair, whereas in other cases the soil will absorb several hours' or even days' rainfall, thus protracting the flow at the commencement, but lengthening it out for several days, it may be, after the weather has become dry.

Distribution of Rainfall.—The amount of water which falls on any field is easily ascertainable from the rainfall statistics of the district, and it may be calculated in gallons of quantity, in cubic feet of measure, or tons in weight, taking 101 tons per acre for every inch in depth of rain. For example, the average annual rainfall of England and Wales is 32 inches, which represents a mean quantity of 723,904 gallons,

or 116,114 cubic feet, or 3,232 tons per acre. But in conducting a work of land drainage, this knowledge of the average annual rainfall is of comparatively little use to us, until we know also the greatest annual rainfall, and the greatest rainfall in any one day during the year. A rainfall of 32 inches per annum, if spread equally over a twelvemonth, gives 1,983 gallons per acre per day; but the rainfall is never thus evenly distributed, and if the size of drain pipes were to be determined on a calculation of this kind, the mistake would soon become apparent. In many cases more rain falls in a single day than will fall for months afterwards. The distribution of rainfall in days, months, and years is therefore quite as important as the average annual amount, and can only be ascertained by careful observation, extending over a long period of time.

The following data, by Mr. Philips, as to the most rapid rainfall in Britain, illustrates very forcibly how the greatest rate of rainfall diminishes according as the period for which it is reckoned is increased.

Period.	Total Depth of Rainfall in Inches.	Rate of Rainfall. Inches per Hour.
1 hour	1	1·0
4 hours	2	0·5
24 hours	5	0·2 nearly

Augmented Rainfall of Districts.—It must also be remembered that the water in the soil may be augmented from two other sources, viz. from springs which burst up from below, and from moisture which finds its way from higher porous strata on to lower ground in a diffused condition. The latter is distinctively known amongst drainage engineers as *water of pressure.* The amount of drainage which may

be needed to counteract these two causes of wetness can only be decided on inspection. The rainfall is a determinate quantity and can be measured, but no rules whatever can be formulated as to the size of pipes necessary to carry off the overflow or outbursts of springs and of water of pressure.

Amount of Rainfall evaporated.—Taking, however, all these three causes of wetness into consideration, we have next to estimate the amount of water thrown off by evaporation from the surface of soils, crops of all kinds and pastures, and from trees. Evaporation goes on at all temperatures, and in a clear atmosphere the higher the temperature the greater the evaporation; but it is not entirely dependent on temperature; dry parching winds also accelerate it. Trees are the most active evaporators; they strike their roots into the ground, and bring up the deep waters, which are given off by every leaf in the form of vapour. Trees, not in a thick wood, have been found to throw off three times the weight of rainfall over the area they cover.

In a series of experiments, Mr. Williams, of Worcester, found the evaporating properties of the subjoined trees and bushes as follows. He weighed successively 100 parts of the leaves of the oak, elm, horse-chestnut, poplar, ash, hawthorn, holly, and Scotch fir; having secured the end of the stem of each from evaporation by means of gum, he subjected them for twelve hours to a July sun, and found them to lose weight by evaporation as follows:—

		Loss.		
Ulmus Campestris	Elm	1-3rd	of its weight	(Exotic).
Populus	Poplar	1-4th	„	(Exotic).
Hippocastanea	Horse Chestnut	1-5th	„	(Exotic).
Cratægus Oxyacantha	Hawthorn	1-6th	„	(Exotic).
Quercus Robur	Oak	1-15th	„	(Indigenous).
Ilex	Holly	1-25th	„	(Indigenous).
Pinus Sylvestris	Scotch Fir	1-50th	„	(Indigenous).

Pasturage is perhaps only second in importance to trees, and, in this respect, corn crops may fairly be reckoned as long grass. But from plants of all kinds, from the bare soil, and from pools and streams of water, evaporation is continually going on.

The mean evaporation, in this climate, during three years' observations, has been found to be very considerable, as will be gathered from the following tabular statement of facts:—*

From the surface of	Yearly Evaporation in Inches.	Comparative Evaporating Power, taking Water as Unity.
Water . . .	18·79	1·00
Ordinary soil .	15·12	0·80
Peat	13·62	0·72
Silt	14·03	0·74
Clay soil . .	13·58	0·72
Long grass .	48·16	2·56
Short grass .	23·50	1·25
Red clover .	53·44	2·83
White clover .	31·15	1·65

Amount of Rainfall absorbed.—In addition to the amount of water actually evaporated from the soil and from plants, &c., the quantity absorbed and retained by vegetation is very considerable. For example, a crop of turnips contains 90 per cent. of water, fresh meadow

* Schubler found the evaporation from soils of various characters to be as follows:—

	Evaporation from 100 parts of absorbed water at 65½° Fahr. in 4 hours.
Silicious sand	88·4 parts
Calcareous sand	75·9 „
Sandy clay	52·0 „
Loamy clay	45·7 „
Pure grey clay	31·9 „
Humus	20·5 „
Garden mould	24·3 „

grass 72 per cent., and even dry hay as much as 15 per cent. of water. On the whole, therefore, we may assume that not more than from $\frac{1}{4}$th to $\frac{1}{3}$rd of the rain which falls will be left for percolation and drainage. With a rainfall of 32 inches, that still leaves for percolation and drainage from 808 to 1,076 tons per acre per annum.

The power of soils to absorb and retain water is extremely various;* but this, though important as

* According to Dr. Anderson, the late able chemist to the Highland and Agricultural Society of Scotland, ordinary arable soil never retains in this way more than half its weight of water, and the lighter and more sandy soils much less; while decomposing vegetable matter (pure humus) is capable of holding nearly four times that quantity, or about twice its own weight. Peat possesses this property to a still larger extent; a specimen of good quality, taken from the surface of a moss, has been found to retain six times its weight, or twelve times as much as an ordinary arable soil, and even after being squeezed between the hands as forcibly as possible, it still retained nearly three times its own weight.

The facility with which sandstones absorb water is illustrated by the quantity of water which they contain both in their ordinary state and when saturated. Even granite always contains a certain percentage of water, and in the dry state is rarely without one and a half pint in every cubic foot. Sandstones, however—even those fit for building purposes—may contain half a gallon per cubic foot, and loose sands at least two gallons.

Limestones contain very large quantities of water, not only in cavities underground, but in crevices of the rock, in spaces between strata, and in faults. Dry compact limestones contain half a gallon of water in every cubic foot. Bath stone contains at least a gallon and some magnesian limestones one and a half gallon. Chalk is as absorbent as loose sand, and contains at least two gallons per cubic foot when saturated.

It is not easy to realise the magnitude of these quantities, although the results have been determined very accurately by calculation and experiment. If we limit our estimate to an area of chalk downs 50 miles in length, 10 miles wide, and 300 feet thick, we shall find that the total rainfall on the surface (taken at 30 inches per annum) will amount to 225,750,000 gallons; while the water contents of the rock, if only half saturated, would be more than 660,000,000 gallons, or nearly three years' total rainfall, and fully 12 years' average supply, even if there were no loss by evaporation, and no circulation underground. It must be evident, then, that there is an unlimited power of absorption in such rocks, and as water is distributed through them rapidly and thoroughly, they may be regarded as large receptacles partly filled, but in which the water is constantly in circulation, rising

regards water supply, does not in any way affect the question of drainage. For all practical purposes it may be assumed that after evaporation and the wants of vegetation have been supplied, the balance of the rainfall, &c., remains to be carried off by drainage. The rapidity with which this amount of water will percolate through the soil is dependent on the density of the soil and its affinity for water, on the depth of the drains, and on the distance between the drains—or, in other words, the angle of inclination; but ultimately it all makes its exit by the drains. It is this water that drainage has to provide for and carry off. Yet cases do occur where, owing to the presence of springs and water of pressure, more water is sometimes discharged by the drains in a single month than falls in rain upon the surface of the field in a whole year. The only safe rule is to provide pipes of sufficient

and falling according to the influence of past and present weather. The longest succession of the driest seasons can never exhaust them; the heaviest rains repeated for years can never fill them. Other absorbent rocks exhibit the same general features in a different degree, and all assist in the general circulation, the water-level rising after rain and sinking by evaporation during drought, so as never to leave the surface either absolutely wet or perfectly dry.

Schubler, in his experiments, found that the power of soils to contain water was in the following degree:—

Kinds of Earth.	A cubic foot of soil weighs		A cubic foot of the wet earth contains of water
	In the dry state	In the wet state	
	lbs.	lbs.	lbs.
Silicious sand . .	111·3	136·1	27·3
Calcareous sand .	113·6	141·3	31·8
Sandy clay . . .	97·8	129·7	38·8
Loamy clay . .	88·5	124·1	41·4
Pure grey clay .	75·2	115·8	48·3
Humus	34·8	81·7	50·1
Garden mould . .	68·7	102·7	48·4

capacity to carry off the greatest possible rainfall, &c., within the shortest period. The greatest fall of rain is not always in those districts having the greatest number of rainy days. In northern latitudes it has also to be considered how far the melting of snows may influence floods in winter or in spring. Very much, at the same time, depends on the porosity of the soil, and the rapidity with which the rainfall or the melting snows will percolate to the level of the drains.

Conditions influencing the Size of Pipes.—It is seen, then, that in deciding upon the proper size of pipe there are a great many conditions to be taken into account. Amongst these we have—

The length of the drain.
The depth of the drain.
The rate of fall.
The distance between the drains.
The porosity of the soil.
The greatest daily rainfall.
The water of springs, &c.
The loss by evaporation and the requirements of vegetation.

Size of Pipes for Minor Drains.—The capacity of the pipe should, properly, be just sufficient to carry off the maximum flow of water, and no larger. If too large it makes the flow sluggish, and is apt to allow the sediment to lodge in the bottom of the pipes, and so eventually choke the drains. Mr. Parkes was a strong believer in the sufficiency of 1-inch pipes for minor drains. He found that pipes of this size, placed 24 feet apart and 4 feet in depth, were able to carry off a fall of rain equal to 2½ inches in 12 hours—a rainfall which is quite unknown in this climate. But with different soils Mr. Parkes might have experienced different results. At any rate, practice seems to say that 1-inch

pipes are not reliable, for they are now never used. The sizes in general use for minor drains, up to say 12 or 15 chains in length, are either 2-inch pipes for the whole, or $1\frac{1}{2}$-inch pipes for the upper ends of the drains and 2-inch pipes for the lower ends. Where the drains are longer, $2\frac{1}{2}$ or 3-inch pipes may require to be used towards the outlet. Small pipes are unquestionably passing out of favour, not only with ourselves but in America. Professor Knapp states that at the late Illinois Tile-makers' Convention only two of the fifty firms represented were manufacturing 2-inch pipes.

Main Drain Pipes.—For main drains the sizes vary from 3 inches up to 18 inches. It is usually reckoned, however, with our average rainfall, that—

	In clay soils.	In free soils.
Pipes of 3 inches diameter will drain	6 acres	4 to 5 acres.
" 4 " "	9 "	6 " 7 "
" 6 " "	25 "	20 " 22 "

The main drains being receivers rather than collectors, their required capacity will always be ample if they are made equal to the united capacity of the minor drains which act as feeders to them. As, however, the latter seldom run full, a smaller-sized main will generally suffice; but if the capacity of the latter has been rightly estimated, the size of the mains ought to be proportioned to them.

Formula for required Size of Main Pipes.—The rule by which to calculate the size of main drain pipes is this:—

> The square root of the number of small pipes multiplied by their diameter will give the required diameter of the main pipe.

Suppose, for example, that there are 16 small drains having 2-inch pipes—

$$\text{Then } \sqrt[2]{16} = 4 \times 2 = 8 \text{ inches,}$$

is the size of pipe required in this case.

Flow of Water through Pipes.—In any calculations as to the discharge of water through pipes of a given size, it is assumed, of course, that the pipes run full, that they are free from twists, straight, smooth, and accurately laid. Even then, water flowing through them has to overcome the opposing forces of friction, adhesion, and the action of water entering the drain. "Friction will be inversely as the diameter of the pipe, and the other forces directly as the agitation of the flowing current. The velocity of the water in different drains will consequently be as the square roots of the respective sizes of their angles of inclination, minus the effect of these counteracting forces." Velocity depends not merely on the amount of fall or inclination given to the drain, but also on the pressure or head of water behind it.

The formula for the discharge of water through straight, or nearly straight, long lengths of circular smooth pipes is—

$$17 \cdot 03 \sqrt{\frac{d^5 h}{1}}$$

d being diameter in inches, 1 length in yards, and h head in feet, the discharge being in gallons per minute.

Assuming that a 12-inch pipe with a fall of 1 foot in 1,100 yards runs full, the discharge will be—

$$17 \cdot 03 \sqrt{\frac{248832 \times 1}{1100}} = 17 \cdot 03 \times 15 = 255 \cdot 45 \text{ gallons per minute,}$$

or say 250 gallons per minute, equal to 15,000 gallons per hour.

Area of Pipes of different Diameter.

Diameter in inches.	Area in sq. inches.	Diameter in inches.	Area in sq. inches.
1	·7854	9	60·617
1½	1·7671	10	78·540
2	3·1416	11	95·033
2½	4·9087	12	113·097
3	7·0686	13	132·732
3½	9·6211	14	153·938
4	12·566	15	176·715
5	19·635	16	201·062
6	28·274	17	226·980
7	38·484	18	254·469
8	50·265		

CHAPTER VII.

LAYING PIPES.

Arrangement as to laying Pipes.—The laying of the pipes should be confided to a careful and trustworthy workman, who is paid day's wages, as more attention in the performance of the work is then insured, than when it is done by the drainer as piece work. In any case, it is best to have the drains cut and filled by one party, and the pipes laid by another. The pipe-layer must be very particular that the drains are of the stipulated depth, the bottoms true and smooth, and the fall properly graduated, before he lays a single pipe; and after laying the pipes, it should also be his duty to put in the first covering of earth, say 3 or 4 inches deep—"blinding" it is called—so as to prevent any displacement of the pipes when the digger comes back to hurriedly fill in the drain.

Imperfect Pipes to be rejected.—As many pipes are found to be more or less warped, great attention is demanded in laying them; such pipes being apt to alter their position after the earth is again filled in, if not well and carefully laid. If a joint is too open, and any two pipes will not fit properly, the workman must take out the last laid pipe and try another.

The Pipes to be laid on a Smooth Bottom.—A very small pebble in the bottom of a drain will sometimes prevent a pipe being laid securely. Or it may

have happened that the digger found it necessary to remove a small boulder from the bottom, thus leaving a depression some inches deep. All such hollows should be rammed full of hard earth before the pipes are laid, so that one end of the pipe laid over it may not be forced down by the superincumbent pressure, and so destroy the continuity of the channel. The pipes should be laid as close and tight as possible, and the clay carefully packed around them, to keep the fine particles of earth from washing in. There is no danger that the water will not find its way in. As we have seen elsewhere, the inlet area, even in the case of the most closely-laid drain pipes, is many times greater than the outlet area of the pipe at the mouth of the drain.

Packing.—It is frequently recommended to pack sod or turf around and over the pipes to keep out sand and silt ; but this practice is far more likely to aggravate the mischief than prevent it. The finest particles of soil are contained in the top spit, and turf or soil is so porous, that, when laid immediately over the pipes, the silt is straightway washed into the drain. In draining quicksands, alluvial deposits, and the like, the only safe plan is to cover the pipes lightly with clay or some solid earth.* In draining the Morecambe Bay intake the pipes were embedded in peat moss, to prevent the fine sand filtering into them. It is also well, in cases of running sands, or other strata of a yielding watery nature, to have the drains bottomed out very quickly, and the pipes immediately laid and covered, so that there may be no displacement of the pipes, by the rising of the bottom or the falling in of the sides.

* In such circumstances the use of collars may be advantageous.

Instruments for laying Pipes.—The common pipe-layer (Fig. 40) is an instrument invented by Mr. Parkes, and is specially adapted for laying round pipes in deep and narrow trenches. The workman, standing on the bank or edge of the drain, hooks up a pipe and deposits it easily and accurately in its right place. On hard and stony soils, however, where the ground is full of small stones and gravel, and where, consequently, the bottom of the drain cannot be cut the exact width of the pipe, and the channel is less true, it is almost impossible to lay pipes satisfactorily by this instrument. In such places, unless laid in collars, or carefully placed in clay, the pipes are very apt to get out of place and thereby effectually stop the drain.

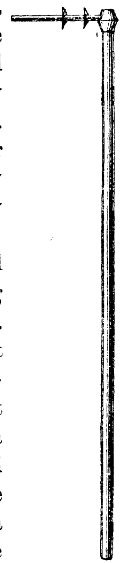


Fig. 40.

In order to obviate this difficulty, and also to prevent the workman displacing the pipes at the moment of packing, Mr. M'Adam, of Bath, contrived an instrument for laying pipes which rendered this displacement impossible. This instrument is sketched in Fig. 41, and consists of a rod of dry ash seven feet in length, and the diameter just small enough for the pipes to thread easily into it, with a socket and handle at one end—the latter of iron, 9 inches in length, and terminating in an eye, set at right angles to the handle, for receiving the rod.

"On the rod so fixed, thread six pipes, when three inches of the rod will remain uncovered; lower the whole into the drain by means of the bent handle, passing the three inches of uncovered rod into the last

pipe in the drain. Leave the six pipes and the machine as they are, in the bottom of the drain, and pack them down firmly with the material excavated from the

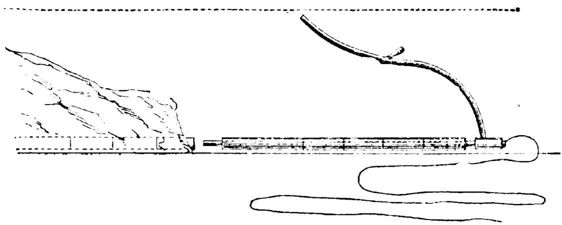


Fig. 41.

drain, even to ramming or treading it in, for it is impossible to displace the pipes by so doing. Then, having packed them tightly, withdraw the machine by means of a long cord, previously hooked to the eye in the socket, standing at some distance up the drain: thread on six more pipes, and proceed as before."

Where to begin laying the Pipes.—In laying pipes with either of the above-mentioned implements, it is best to begin at the lower end of the drain and work up the hill. Where the pipes are laid by hand, however, this plan is just reversed; it is then found better to begin at the top, and lay the pipes down the hill, the workman walking backward in the trench, and taking the pipes from the bank, where he had previously placed them so as to be conveniently within his reach.

Cost.—Pipe-laying, as already said, is best done at day's wages; but it is often done by the piece. Where piece-work is preferred, the price paid in this country varies from one halfpenny to one penny per rod, of 5½ yards, according to the character of the trench bottom. A workman good enough to be entrusted

with pipe-laying will expect to earn at least 4*s.* per day, so that at $\frac{1}{2}d.$ per rod he ought to be able to lay at least 96 rods of drain in a day, and at a 1*d.* per rod not less than 48 rods. The price is the same whether the pipes are laid by hand or by the aid of the pipe-layer.

Junctions.—The junctions between the pipes, of both small and main drains, should be very carefully made. Junction pipes for the purpose, that is, pipes having the first branching pipe of the parallel drain fixed to the pipe of the main drain, should be got from the tile-works. If it is impossible at any time to obtain these junction pipes, the holes into the leading pipes require to be fitted very exactly, and clay firmly rammed all round about. The man laying them should carry a tool for dressing warped pipes, and a sharp chisel and mallet for taking out holes. A miniature pick-axe is often used for these purposes, and is at the same time useful for smoothing any irregularities that occur in the bottoms of the drains.

Junctions should not be made at right angles. This impedes the flow. It has been found, for example, that where the resistance due to a junction at right angles was 316, that due to a curved junction of 5 feet radius was 146, while that for a curved junction of 20 feet radius was only 100; thus showing the increase of resistance with a junction at right angles to be over 200 per cent. over the junction of 20 feet radius.

But this is not all; attention should be paid to the manner in which the curved junctions are laid down. Thus it is too frequently the way to join the curve to the pipe by a hole placed in the middle of the periphery of the latter, instead of level with the bottom. The gain of effective discharge by the adoption of curved

junctions over junctions at right angles, is in many cases rendered nil by neglecting to join the curve at the bottom of the pipe. The practice here recommended prevents any deposit lodging in the bottom of the main pipe.

Order of Working.—The rule in making drains is to begin with the complete formation of the main drain, and then proceed with the parallel drains, from the point where they enter the main drain to their upper extremity. In filling up, the order is reversed, and the completion of the drain commences at the upper end, and proceeds to its termination at the entrance with the main drain. It is desirable to have the entire length of the drain opened before any portion of it is filled in, so that a right inclination may be secured; but whether this can be done or not depends on the nature of the soil. If the sides will not stand, the pipes must be laid, and covered in immediately the digging is finished.

Filling-in Drains.—The earth when returned to the trench after the pipes are laid should occupy the same position as it did before it was excavated, that is, the top spit which was first in the digging should be the last to be filled in. It is a mistake to believe that the bottom clay will do harm if put next the pipes. The air which enters the soil through the pipes will soon oxidise the clay and prevent it from either cracking or puddling. The earth as it is filled in should be well packed and rounded up to the land level, so that no open channel remains to draw off water from the surrounding surface. On old grass lands a halfpenny per rod extra is usually allowed for replacing the turf.

CHAPTER VIII.

COST OF DRAINING.

The cost of draining is principally dependent upon the labour of cutting and filling the drains, the material composing the drain, and outlet for discharge. This last varies with the ground, and can only be included in a general estimate where the surface is undulating. It was formerly held that the cost was equally divided between the labour and material, but with the introduction of drain pipes, and especially since the improvements in making them, there is a considerable balance in favour of material.

The following table shows the number of rods and the number of pipes per acre, with drains at various distances apart:—

Distance between the Drains.	Rods ($5\frac{1}{2}$ yds.) per acre.	12-inch pipes.	13 inch pipes.	14-inch pipes.	15-inch pipes.
Feet.					
15	176	2,904	2,680	2,489	2,323
18	146	2,420	2,234	2,074	1,936
21	125	2,074	1,915	1,778	1,659
24	110	1,815	1,676	1,555	1,452
27	97	1,613	1,489	1,383	1,290
30	88	1,452	1,340	1,244	1,161
33	80	1,320	1,219	1,131	1,056
36	72	1,210	1,117	1,037	968
39	67	1,117	1,031	957	893
42	62	1,037	958	888	829

"The differences in the quality of soils, that lead to differences in the depth and distance of the drains, are also such as to affect the cost of digging the drains. An increase of depth necessarily causes an increase of cost, from the circumstance of more earth having to be moved. But the same reason that causes drains to be made closer, namely, the stiffness of the soil, renders them more difficult to dig, and hence increases the price of digging. This will explain how it happens that the cost per rod is often greater, not only as the depth increases, but as the distance of the drains is less. Of two soils drained at the same depth, the expense of draining a rod (provided both are alike free of stones and boulders) will be least in that where the drains are farthest apart, which is where the soil is of the freest or least tenacious description."

The cost of cutting and filling varies from 4*d.* to 1*s.* per rod of 5½ yards, according to the depth of the drain and the hardness of the substrata. In Gloucestershire at the present time 3-feet drains cost from 6*d.* to 8*d.*, and 4-feet drains from 8*d.* to 10*d.* per rod.

From Banffshire, Mr. C. Y. Michie writes: "Drainage work is now from 10 to 15 per cent. cheaper than it was three years ago. The present prices for 3½-feet drains in Banffshire, including cutting, laying tiles, and filling in, is from 13*s.* to 17*s.*, according to soil, per 100 yards." Reducing Mr. Michie's yards to rods, and deducting 1*d.* per rod for pipe-laying and finishing, the cost of cutting and filling, as given by him, is found to be 7½*d.* to 10½*d.* per rod.

In his evidence before the Royal Agricultural Commission Mr. Bailey Denton, speaking as to the cost of drainage, says: "When I began draining in 1849 I was paying 1*d.* per yard run for 4-feet drainage. That

is $5\frac{1}{2}d.$ a rod of $5\frac{1}{2}$ yards. I now pay 7*d.* to 8*d.* a rod for the same thing. . . . . I should say that the increased cost of draining has been 35 per cent."

Suppose the drains are made 3 feet deep, and cutting and filling costs 7*d.* per rod, then the

COST PER ACRE AT DIFFERENT WIDTHS WILL BE:

—	18 feet apart.			21 feet apart.			24 feet apart.			27 feet apart.			30 feet apart.			33 feet apart.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
Cutting and filling	4	5	2	3	12	11	3	4	2	2	16	7	2	11	4	2	6	6
Pipes, 14 in. long and 2 in. dia. at 25*s.* per 1,000..	2	11	$10\frac{3}{4}$	2	4	$5\frac{1}{2}$	1	18	$10\frac{1}{2}$	1	14	$6\frac{3}{4}$	1	11	1	1	8	$3\frac{1}{2}$
Allowance for mains and outlets	0	3	6	0	3	9	0	4	0	0	4	3	0	4	6	0	4	9
Pipe-laying, at $\frac{3}{4}d.$ per rod	0	9	$1\frac{1}{2}$	0	7	10	0	6	$10\frac{1}{2}$	0	6	$0\frac{3}{4}$	0	5	6	0	5	0
Cartage	0	4	3	0	4	0	0	3	6	0	3	3	0	3	0	0	2	9
Superintendence .	0	4	9	0	4	6	0	4	3	0	4	0	0	3	9	0	3	6
Total......£	7	18	$8\frac{1}{4}$	6	17	$5\frac{1}{2}$	6	1	8	5	9	$11\frac{1}{2}$	4	19	2	4	10	$9\frac{1}{2}$

The cost per acre, it is seen, ranges on the above scale from £4 10*s.* $9\frac{1}{2}d.$ at 33 feet apart, to £7 18*s.* $8\frac{1}{4}d.$ at 18 feet apart. Deeper drains in hard soils will cost more in cutting; but upon easy digging soils 3-feet drains will be accomplished at considerably less than 7*d.* per rod.

Drainage Companies' Charges.—Under the Public Money Drainage Act of 1846, Land Improvement Companies have undertaken and carried out a great deal of the land drainage that has been done in this country. These companies have undoubtedly afforded great facilities to landlords who wished to borrow money for the improvement of their estates.

The charges made by these companies are moderate.

For loans under £500, repayable, principal and interest, in thirty-one years, the charge is £6 7*s.* 7*d.* per centum per annum; which is calculated at 5 per cent., the difference being the amount paid off the principal. For loans above £1000, the charge is calculated at 4½ per cent., and amounts to £5 16*s.* 8*d.* per centum per annum, when spread over twenty-five years. If we take the present cost of drainage at £7 per acre, the annual charge on this sum would amount to 7*s.* or 8*s.* per acre.

It has no doubt been advantageous to many tenants to pay an extra rent of 7*s.* or 8*s.* per acre, in return for getting the wet lands they occupied drained; but in paying land improvement rates, calculated to redeem both principal and interest in twenty-five or thirty-one years, as the case may be, the tenant, let it be remembered, bears the whole cost of the improvement. It is right and fair that the occupier for the time being should pay simple interest on the outlay, seeing he is to reap any increase in the produce of the land. The redemption-money, on the other hand, ought clearly to be chargeable on the landlord, whose property is *permanently* increased in value by the improvement.

Of course, if a tenant is taxed on his own improvements, by having his rent permanently raised, after redeeming the outlay, he has good reason to object. To this, and to the after expenses attendant on successful drainage, which if borne at all must be borne by the occupier, Mr. Bailey Denton attributes the fact that the amount of drainage executed in this country has been declining for the last ten years. In his evidence before the Royal Agricultural Commission, he says: "The disinclination of tenants to pay the increased rents necessary to relieve their landlords of

loss after borrowing the money, and the consequent indisposition of the landlords themselves to lay out money in drainage, is due in a great measure to the fact that to develop the full benefit of under-drainage, and counteract the effect of successive wet seasons, when several follow each other, involves considerable outlay on the part of tenants, in deeply cultivating the surface, and in laying flat lands which are formed in ridges and furrows. . . . But owing to the additional expense of these after operations, the work is seldom done, and so the full benefit of the drainage is never obtained. The tenant, however, pays up the outlay through compound interest, and the letting value of the land is permanently increased, at the tenant's expense, and to the landlord's advantage."

CHAPTER IX.

DRAINAGE OF TIDAL LANDS.

THE drainage of tidal lands, or lands where the surface, although above low-water mark of ordinary tides, is yet below high-water mark, involves many points in addition to those already mentioned. In this case there can be no discharge of the drainage waters by natural means, except in certain states of the tide, and in order to keep out the flood waters at high tide the lands usually require to be embanked.

Polders.—The drainage and cultivation of tidal lands thus always becomes a work of reclaiming them from the sea. Hence the name *polder*, given to the old enclosures in Zealand, signifying "a land won from the sea." Nearly the whole of Holland is one vast *empolder*; and as some of the richest and most fertile soils are to be won by this means, enclosures of this nature are to be found on the seaboard, and on the banks of tidal rivers, in every inhabited part of the World. It is estimated that in Great Britain alone from one and a half to two million acres of land have been thus won from the sea.

Effect of Salt Water on Land.—Many of these empolders are of course *fresh-water* marshes, but the conditions of drainage in such cases are almost similar to where the lands are direct intakes from the sea.

In connection with these salt-marshes, it may be mentioned as a curious fact, that land which has been once covered by the sea and has been reclaimed grows wonderful corn crops, but if the sea ever gets on it again it entirely destroys the power of growth until the land is freed from salt.*

Embanking.—Before the drainage of tidal land can be proceeded with, the tidal waters must be shut out by means of an embankment; and in many places the whole of the proposed intake has to be surrounded with an embankment, to keep out the flood waters from the higher grounds behind, as well as on the sea or river frontage.

Arrangement of Drains and Level of Main Canal.—After embanking the lands, a work which will be dealt with in the succeeding chapter, the field drains are laid out, and connected with the drainage canal or receiving trench. According to Rankine, the low-water level of this main drainage canal should be above that of low water of neap tides to the extent of $\frac{1}{15}$th part of the rise of such tides, and the top-water level of the canal is to be fixed so as to give sufficient declivity to the branch drains. "The space contained in the canal between these levels is the *reservoir-room*; and inasmuch as the length and depth of that space are fixed, the breadth midway between the levels is to be made sufficient to serve as reservoir room for the greatest quantity of drainage water that ever collects during one tide. The depth of the canal must be made at least sufficient to enable the whole of that quantity of water to be discharged in the intervals between one hour before and one hour after low water, the mean velocity of outflow being assumed to be about equal to

* Hon. C. Gore. Evidence before Royal Agricultural Commission.

that due to a declivity of the height between high and low water levels in the whole length of the canal, and its hydraulic mean depth, when full, up to the middle water-level."*

Amount of Fall necessary for Main Drainage Canals.—As tidal lands usually present a perfectly level surface, those engaged in the drainage of them

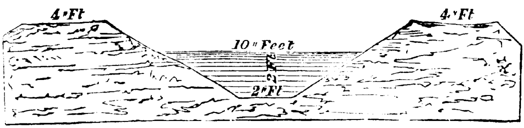


Fig. 42.

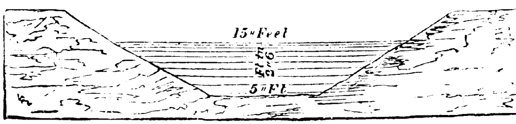


Fig. 43.

Fig. 44.

are often discouraged by the difficulty of obtaining sufficient fall for the drains. It has, however, been proved in practice that a main drainage canal or trench, "30 feet wide and 6 feet deep, giving a transverse sectional area of 180 square feet, will discharge 300 cubic yards of water in a minute, and will flow at the rate of one mile per hour, with a fall of no more than 6 inches per mile."† In every case where that amount of fall can be given to the main canal, it may, therefore,

* Rankine. † Mr. Smith, of Deanston.

be relied on as ample and sufficient. Figs. 42, 43, and 44 represent sections of drains of large size adapted for works of the kind here referred to.

Demerara Field System.—In British Guiana, where all the lands under sugar cultivation have been reclaimed from the tides, and the surface of the fields is 4 to 5 feet below the level of ordinary high-water mark, the drainage question has for many years been a standing difficulty with the planters.

Most of these lands were empoldered by the original settlers, the Dutch, in the eighteenth century. A front dam is thrown up against the sea, a back dam against the savannah and bush waters; and also two side-line dams. The rainfall and drainage waters are discharged through a koker or sluice placed in the front dam; and usually a small koker is put in aback, to take in fresh water for the navigation trenches, and also for field irrigation in dry weather. The empoldering done nowadays is seldom more than taking in a fresh depth aback of the older cultivation, which right is secured to most of the estates in their grants of the lands.

Drainage and Navigation System.—When the dams are made up, and the land cleared, the navigation and drainage systems are next laid out, and the field outline and plan is then complete. First a main drainage trench is opened behind the front dam, and carried round the inner side of each side-line till it reaches the back dam; these trenches being in part at least dug out in forming the dams. Next, a centre main navigation canal is dug from the back dam to the buildings in the front of the estate, with a walk alongside the canal called the middle-walk. Then at every 36 rods along this centre canal, at right angles, right and left, are dug smaller trenches, which are connected

with the main one, and the navigation system is complete. Each field is thus 100 × 36 = 3,600 rods, 12 acres. Each field is again divided into 12 beds, by eleven open drains, each 2 feet wide, and opening into the side-line trench, which thus receives the dis-

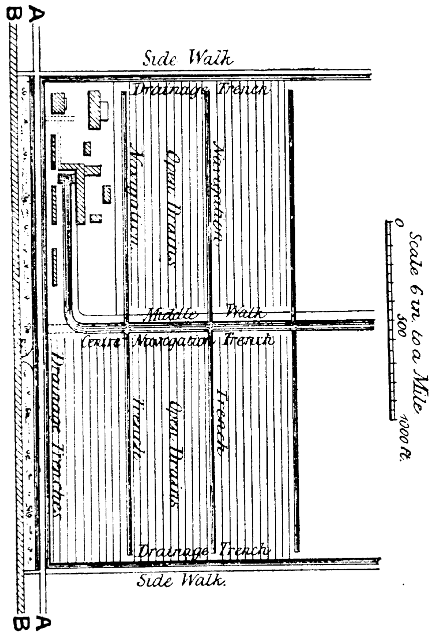


Fig. 45.

charge of all the small drains from the back to the front dam, where the koker lets the accumulated waters out to sea at low tide.

The internal arrangement of the estate thus resembles a system of irrigation on a large scale, in which the middle-walk canal is the feeder, and the cross

canals the irrigating channels, the drains drawing off

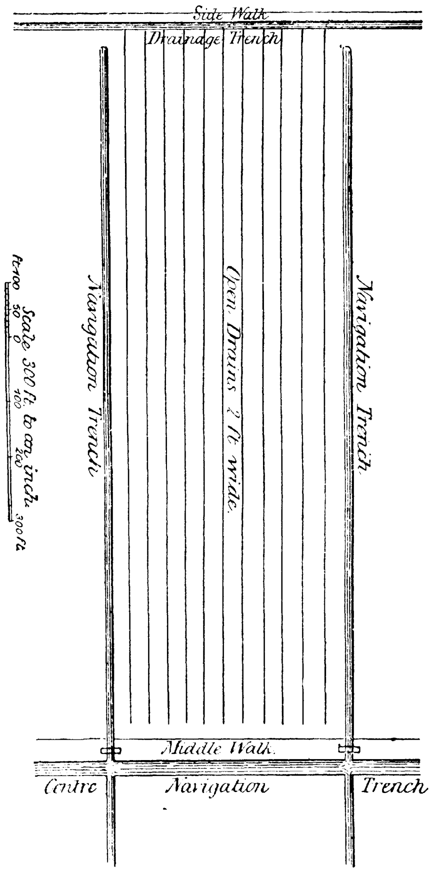


Fig. 46.

the surplus water which is passed on by the side-line trenches to the sluice or koker. Fig. 45 shows the field

system in Demerara, and Fig. 46 the drainage and navigation system.

Evils of the Open Drain System.—It will be seen that this open-drain system causes an enormous waste of land. That, however, is the least loss. Land is cheap in Demerara, but labour is dear, and the open drains must be held responsible for the costly system of field cultivation which is necessitated from the obstacle thereby offered to implement tillage; not to mention that the open drains and trenches give increased labour and trouble by propagating the spread of water grass and weeds, which are terrible pests in that tropical climate.

Experiments in Tile Drainage.—The emancipation of the slaves, and the removal of the protective duties which had long favoured colonial sugars, doomed the old Demerara system of cultivation. From these days forward the planter has been struggling with a difficulty which can be surmounted only in one way. When the crisis of 1846 made the need of a rational system of agriculture so severely felt in the colony, the important experiment of subsoil drainage was attempted. A field on Plantation La Pénitence was granted for the purpose, the Combined Court having previously voted the sum of 2,000 dollars towards defraying the expenses of the experiment, which was carried on under the immediate superintendence of Dr. Shier.

"The field," says Mr. McRae, one of the Committee appointed to watch and report, "was tile-drained with three-inch tube tiles, laid in drains 15 feet apart, running from the inner end of the field to a reservoir at the outer end, adjoining the main draining trench of the estate, but separated from it by a dam.

"The distance from the one end of the field to the

other was about 45 roods, Rhynland measure, and the fall given to the tiles about 10 inches in that distance; they having been placed 20 inches under the surface of the land at the upper end of the field, and 30 inches at the lower end, or reservoir. There was a four-horse high-pressure steam-engine employed to pump the water received in the reservoir from the tiles into the side-line trench of the estate, which was run off every tide. Every possible justice was done in digging the drains and in laying tiles with mathematical precision, they were covered over with divots, and the drains packed with clay; the whole field being stiff clay soil.

"There was an adjoining field of about the same area cultivated with open drains in the ordinary manner. The result of this experiment for the first crop was, that the thorough-drained field gave about 75 per cent. more sugar than the open-drained field, and made very nice sugar, which sold 1*s.* 6*d.* per cwt. over the price obtained for the sugar from the open-drain field."

The effect of this flattering prospect was electrical and instantaneous. For the time being everybody believed in and was ready to extol the advantages of tile drainage. It was the one thing needful to the prosperity of the planter. Resolutions in its favour were immediately adopted by the Honourable the Court of Policy of the Colony of British Guiana, and petitions to the same effect were signed by all the members of the Combined Court, by the whole body of proprietors and planters, and by hundreds of other residents in the colony, praying the British House of Commons to grant a loan of money to be expended in draining the sugar plantations.

An Extract Minute of the Court of Policy, of March 1,

1847, which I find in one of the blue-books of that period, and a petition annexed to it, contain a series of resolutions on the subject, amongst which are the following:—

"*That* one of the greatest difficulties with which the planters have to contend is, that the system of drainage in universal use in the colony is only adapted to a state of society such as existed prior to the emancipation, when manual labour for every field operation was abundant, effective, and cheap.

"*That* this system of drainage, known as the open-drain and round-bed system, is altogether incompatible with the employment of cattle labour, the use of the most approved implements, and with the introduction of the numerous improved methods of agriculture so well known elsewhere, and which, but for this obstruction, would be at once gladly adopted.

"*That* it can be shown that, were the planters enabled to adopt a more perfect system of drainage, admitting of the 'thorough-drainage,' and laying flat of the surface of the cane-fields, many of the difficulties under which they at present labour would be obviated.

"*That* it is the opinion of this Court that the following, among other advantages, would accrue:—

"(1.) The general use of cattle labour and implements, whereby the present difficulties in respect of high-priced, ineffective, and incontinuous labour would be greatly reduced.

"To illustrate this point more fully, your petitioners may state that in the best farmed districts of Scotland, on a liberal computation, which embraces both green-crop weeding and harvest work, six adults, with four good Clydesdale horses, two ploughs, and the other implements corresponding to the two ploughs, are

known to labour 100 acres on the four-course rotation. In this colony, to cultivate 100 acres and manufacture the produce, fifty negroes, working well and continuously, are required. But as the Scotch labourers only partially manufacture the produce, and our labourers both cultivate the sugar-cane and manufacture the sugar, it is but fair to double the number of Scotch labourers per 100 acres, to secure a fair comparison. Hence it follows, that the four horses, two ploughs and corresponding implements, effect a saving of thirty-eight labourers per 100 acres of cane cultivation and manufacture, a saving which it is obvious that no measure of immigration can possibly supply to the colony at the same cheap rate, even if it were otherwise equally valuable.

"(2.) That the introduction of all the well-known improvements in agriculture applicable to the colony, as appears both from a consideration of principles and from the experience of other colonies, would be rendered in this colony practicable and easy.

"(3.) That the quantity of the produce would be increased, and its quality improved.

"(4.) That cane cultivation would be less liable to the effects of protracted wet and drought, which at present occasionally interfere with the large returns which might otherwise with considerable confidence be relied on.

"(5.) That the effect on the labouring classes themselves, of substituting improved implements for the present very imperfect methods, would be highly beneficial, and would tend to improve and elevate the condition of such especially as already possess small lots of land, the want of efficient drainage being a main cause of the very limited and imperfect cultivation of almost all such lots.

"(6.) That improved drainage and cultivation of the soil would be found to prevent disease, to moderate the virulence of epidemics, and to improve the general health of the community."

In forwarding the Resolutions and Petitions to Earl Grey, who was then at the Colonial Office, Governor Light warmly supported them in his accompanying despatch, and earnestly recommended the subject to his lordship's favourable attention.

Earl Grey's refusal to support the petitions to Parliament caused the colonial ardour for tile-drainage to subside as rapidly as it had arisen. Without debating the policy of such a loan, there is no reason to doubt that, had it been granted, the planters would have earnestly set about the work of tile-drainage, and speedily have solved for themselves all the difficulties in the way of its successful application. But it was fated to be otherwise. The loan for drainage was not forthcoming from the mother country, and the colonists turned their whole energies in the direction of immigration, on which, though only affording a temporary solution of the difficulty, they were not slow to provide and to expend much more than the amount of the loan they had asked for to enable them to tile-drain their lands. The La Pénitence experiment was neglected, or imperfectly carried out, and it seems to have been abandoned altogether at the end of the second year, after some 5,000 dols. had been uselessly expended upon it. But having quoted Mr. McRae's account of the early part of the experiment, let me give the conclusion of it in his own words.

"During the second year," he says, "the drains began to exhibit symptoms of silting; and notwithstanding the reservoir being kept pretty clear of water

by the pumping-engine, the field got frequently inundated during heavy rain. At the expiry of two years, I examined the tiles at various distances from the reservoir, and found them to be nearly silted up at the upper end of the field; the silting in them gradually diminishing as I approached the reservoir, until within two rods of the reservoir, where the silting disappeared entirely. In consequence of this silting, and the inundations caused thereby, the canes on the upper half of the field were puny and miserable, gradually improving, however, towards the reservoir. The result of this year's crop showed a falling off of nearly 100 per cent. as compared with the yield of the previous year, and the sugar also fell off much in quality. I watched this experiment from first to last, with great attention and much interest, *because I saw clearly that by a successful system of thorough drainage the prosperity of the Colony would be materially secured*; inasmuch as two-thirds of the manual labour now employed in cultivating the land would thereby be saved, and brute labour substituted in its stead. The land under thorough drainage would then be a perfect level, and every facility afforded for the use of the plough, and all other agricultural implements worked by quadrupeds; whereas, at present, under a system of open-drainage, it has been found profitably impracticable, and manual labour is the sole power employed to cultivate the soil."

When the next attempt was made at tile-drainage in Demerara is immaterial. Little or nothing seems to have been done at it during the 20 years succeeding 1846. Since 1866, however, it has gradually progressed, until at length it begins to assume no inconsiderable proportions. But even now, there are not perhaps

more than 2,000 acres tile-drained, out of some 150,000 acres under cultivation in the colony.

Objections against Tile Drainage answered.—There is no doubt that pipe drains, under the Demerara conditions of soil and rainfall, are very liable to get choked up with silt. But it is obvious that silt can only enter the pipes by one of two ways—either downwards through the superincumbent soil, or from the mouth of the drain. If the silt enters the pipes from above, the presumption is that the drains are too shallow, or that the pipes have been improperly laid; and the remedy will be either to deepen the drains, or to secure the pipes by laying them in collars, or by packing them around with clay. If the silt enters the pipes by the mouths of the drains, there are also two ways of effectually guarding against it: *first*, by trapping the mouths of the drains; *second*, by always keeping the water in the drainage canals at a lower level than the drain outlets.*

The remarks of Mr. McRae show that in the La Pénitence experiment the silt entered the pipes by the mouths of the drains, and not from the soil above. If the latter had been the case, the silt would have accumulated towards the mouth of the drain; but Mr. McRae says that the silt was greatest at the upper end of the drain, and that it gradually diminished towards the lower end, which is proof positive that it must have entered by the mouth of the drain. This being so, it could have been prevented by trapping the drains, or by constantly keeping the water in the drainage canals below the level of the drain pipes—by natural means if possible, but by the aid of machinery if needful.

* As an additional precaution, it may be wise to have one or more deposit cisterns built in the drain, to catch any silt that may enter the pipes.

Another objection urged against tile drainage in Demerara is, the excessive humidity of the climate, and the declared impossibility of underground drains to carry off the immense rainfall with sufficient rapidity. It is thought, by those who argue thus, that there is nothing to equal the capacity of open drains and ditches for storing water. This of course is entirely to mistake the purpose of a drain. Yet, if it comes to be a question of storing the water, the body of the soil, aerated to a depth of 3 or 4 feet, has a far greater capacity than any number of open drains. All that is required is to keep the cask running, so as to renovate day by day the water contained in the soil; and this will be found advantageous to the planter in more ways than one. It has been calculated that no less than one-fourth the entire bulk of a moderately well pulverised and moist soil is made up of contained air, so that every foot in depth of this soil is capable of facilitating the escape of water from the surface to the extent of 18,817,920 cubic inches of rainfall per acre. Therefore, apart altogether from the benefits resulting from the renovation of water in a soil, which subsoil drainage alone effects, the open-drain system is not the best one for dealing with a heavy rainfall.

The want of a good outfall is also alleged to be an insuperable obstacle to subsoil drainage in Demerara. This, however, does not weigh more against covered drains than against open drains. Whatever natural drainage there is, it will serve as well for the one system as for the other; and the necessity for aiding the discharge by means of machinery is not at all increased by the adoption of underground drainage.

Natural Drainage.—On the coast of British Guiana the land level, as already mentioned, is about 4½ feet

below the level of high water. The following section, Fig. 47, shows the relative levels of the land and of the sea at low water. Spring tides rise from 8 to 9 feet, and neap tides 4 to 6 feet. The average rainfall of the colony, from observations during ten years, is 102 inches; the maximum annual rainfall in that period being 133 inches and the minimum 68 inches. A fall of 6 inches of rain in 24 hours is not unknown in Demerara, and this is in fact the amount of drainage

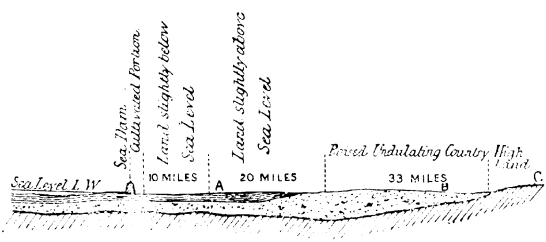


Fig. 47.

water which has to be provided for where the discharge is entirely dependent on natural means. The proportion of the rainfall which is absorbed and evaporated is scarcely appreciable,* even in that tropical climate, during a succession of rainy days, although it amounts to a great deal annually, so that the maximum rainfall during any one day is practically the amount of drainage water which has to be discharged from the embanked area. The quantity of water, therefore, which in this case has to be stored up till the drainage can be opened in the period of any one tide, can seldom or never exceed a rainfall of $1\frac{1}{2}$ inch, which on an estate of 500 acres will be equal to 2,733,750 cubic

* The greatest evaporation in 24 hours, during three years' observation, was ·210 inch.

feet. This is an excessive estimate, perhaps, even for Demerara. In the United Kingdom the greatest rainfall to be provided for in a similar period of time would not exceed half an inch per acre.

Where less than this amount of water can be retained within the enclosure, in the drainage canals and in the pores of the soil, during high water without submerging the drains, some mechanical means will have to be employed, if the land is to be perfectly drained. It is

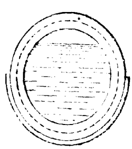


Fig. 48.

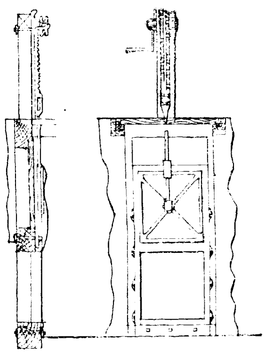


Fig. 49.

well, however, in all cases, to take advantage of natural drainage as far as possible.

The Sluice or Koker.—The drainage outlet is either a sluice, or a cylindrical iron tube or koker. The latter is fitted with a self-adjusting valve door on the outer end, and is usually made 6 feet in diameter, thus affording a sectional area of 28·274 square feet (Fig. 48). The sluice is a vertical doorway, or sliding valve, of timber or iron, moving in guides, and set in a rectangular passage of timber or masonry, the valve being worked by a winch and racket, or by gallows-posts and

windlass (Fig. 49). It is usually made to open 13 feet at the base, so that with 6 feet of water on the cill, the sectional area is 78 square feet. With the same periphery the circular koker, if it runs full, will carry more water than the rectangular sluice; but with a small run of water the sluice, with its flat base, has a decided advantage.

Number of Sluices.—One or more large sluices, of the above size, will generally be preferable to a greater number of smaller ones. The expense of these large sluices, and also their danger from the sea, is against them; but the consideration of their stream being powerful enough to keep open the channel to sea is in their favour. In Demerara a single koker usually serves to drain a whole estate, which may be from 500 to 2,500 acres in extent. But the number of acres to be drained by one koker or sluice must be a matter of local experience, as it depends on many conditions besides the sectional area of the water-way.

Level of Sluice Cill.—The level at which a sluice or koker is put in is a point of great practical importance. Where the land is at a very low level, and there is sufficient current to keep the cill of the sluice free from silt, the cill may be laid at the level of low-water mark. If there is no current, however, the cill of the sluice should be placed as far above this level as is consistent with a proper depth of the trenches. It is doubtful if, under any circumstances, anything is gained by having the cill of the sluice below low-water mark. This, however, is often done, with a view to deepening the trenches within the embankment; but as by so doing the head or pressure of water is not increased, there is no advantage. On the contrary; by lowering both the trenches and the cill of the sluice,

the length of run between tide and tide is shortened, and the water, in times of heavy rains, will then actually stand higher in the drains than if the cill of the sluice had been at low-water mark. The maximum run of from 6 to 7 hours is only obtainable by having the bottom of the front draining trench somewhat above the level of low water. The cill of the sluice should be as nearly as possible on the same level. Tidal lands, unfortunately, are seldom elevated enough to admit of this, but in proportion as the cill of the sluice is lowered to low-water level, or below it, the run is shortened, and at neaps, or when the tide is kept up by winds, the drainage is liable to be greatly interrupted.

Forcing an Outlet.—On nearly all tidal lands the natural drainage is frequently impeded by the tides bringing in drift mud, which fills up the sluice channel, and it is a matter of the first moment to keep this channel open. The straighter and the deeper the outfall channel is, the greater and quicker will be the discharge of water. A mode of forcing drainage has been introduced on some of the Demerara Estates, by Messrs. Fowler & Co. of Leeds, and is simply as follows :—A wire rope is laid down the full length of the water course to be cleared and is anchored at the far end. One or more punts, each fitted with an engine and clip pulley, run along the rope, in a similar way to the chain haulage on canals. Behind the punts is attached a set of harrows, which stir up the mud, which in the current of the receding tide is carried out to sea. In this way a channel is made and is afterwards kept clear.

The above-mentioned plan of forcing drainage is not so effectual as having artificial scours by means of reservoirs, relieving basins, or canals and sluices.

canal extending perhaps miles in length, and containing vast quantities of fresh or sea water, if kept full and let off at low water, is able to continue running in plenty for a considerable time with great velocity, and has a very powerful effect in clearing the channel.

The early settlers in Demerara adopted this plan. In laying out their plantations, a space was left between every second estate for a Company canal, which was made available both for forcing drainage and for facilitating navigation. When the water from the creeks or lakes behind the estates gave out in dry weather, advantage was taken of the tidal water to fill the canals. These Company canals, as they are called, are of the greatest value in helping to maintain an efficient system of natural drainage; and recent efforts to improve the drainage of estates have been wisely turned in this direction.

Mechanical Drainage.—If, after taking every precaution to ensure good natural drainage, this fails to keep the level of the water in the trenches sufficiently low to admit of a free and continuous run from the field drains, the natural drainage must be supplemented by mechanical agencies.

On many of the Demerara estates the drainage is now entirely effected by steam power, but this is not to be recommended. Mr. Russell, a leading planter in the colony, puts the first cost for draining plant and engine, equal to the drainage of 600 acres, at not less than £5,000, and the annual charge attending the same at £2 per acre, viz. 24*s.* per acre for fuel and labour and working, and 16*s.* per acre for interest on capital and wear and tear of machinery.

This shows the necessity for taking advantage of natural drainage as far as possible, and of putting the

draining-engine to other uses when it is not required for pumping.

The most economical plan of conducting drainage in this manner, "is to provide reservoir room for the greatest floods, and pump constantly at an uniform rate. To provide for the repair of engines, and for accidental stoppages, engines are required in reserve, of power equal to from one half to the whole power of those that are kept at work." *

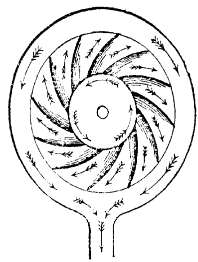


Fig. 50.

The centrifugal pump (Fig. 50) is specially adapted to the lifting of large bodies of water to moderate heights. Its essential parts are—(1) the wheel to which the water is admitted at the axis, and from which it is expelled at the circumference, by the centrifugal force due to the rotary motion imparted to it in passing through the rapidly revolving wheel; and (2) the casing or box in which the wheel works, and by which the entering water is separated from that discharged.

One of Appold's centrifugal pumps, 4 feet 6 inches in diameter, employed in draining Whittlesea Mere, and in keeping up the drainage of 3,000 acres of Fen land, discharged 16,521 gallons of water (equal to 74½ tons) per minute, with a lift of 5 feet. The pump in this case was worked by a 25-horse-power engine, and used on an average 60 hours a week; the cost, including coal, oil, repairs, and engineman's wages, was less than 2*d.* per hour for every horse-power employed. The cost of draining the 3,000 acres was thus £675, being 4*s.* 6*d.* per acre per annum.

* Rankine.

The great rotary pump, which discharged the enormous cascade of water at the "Centennial" Exhibition at Philadelphia, was able to throw 100,000 gallons per minute. The principle upon which this powerful pump works is that of an ordinary propeller shaft. It is rotated by means of a pulley and a belt from an engine. The shaft is enclosed in an iron casing or tube, and the water is forced up the outflow pipe. Fig. 51 shows a section of this pump.

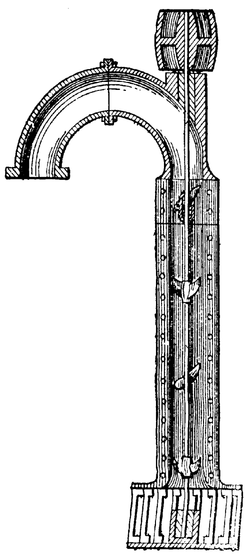


Fig. 51.

"Both in this country and in Holland, windmills were formerly much used for working drainage pumps. This is of course a cheap motor, but experience has shown that the power is too variable to be relied upon for keeping the water to a certain level, which is essential for successful agricultural operations; hence many of the older windmills have been abandoned and replaced by steam-engines, or, if the windmills are retained, they are only used occasionally. The cost of maintenance of old mills, however, is so heavy, that it is often found more economical to take them down and work the pumps by steam. Even in countries such as Egypt, where coal costs from £2 to £3 per ton, or even more, and where there is a steady breeze for several hours almost every day, the windmill is too uncertain a motor to be universally

employed. Many other instances might be adduced, but the two extremes, Holland, where coal is relatively cheap, and Egypt, where it is dear, will probably suffice to show that there are comparatively few conditions under which wind power can be economically employed for drainage."

For low lifts, scoop-wheels, worked either by steam power or by windmills, may sometimes be usefully employed instead of pumps. The slow speed of

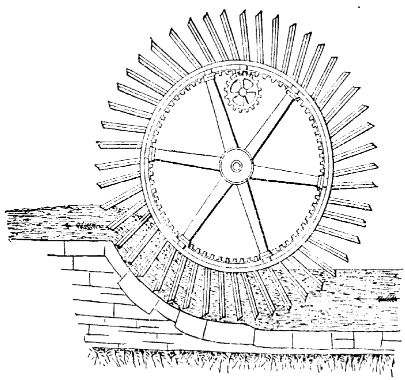


Fig. 52.

working and the ample wearing surfaces are in favour of a low cost of maintenance; but the first outlay will be less for a centrifugul pump than for a scoop-wheel of equal capacity. The flash-wheel is much used in the Fen districts for raising water rapidly short distances. "It is like an undershot-wheel with its motion reversed; in Fig. 52 the arrows show the direction of the current when driven upwards. It must of course be made to fit the channel closely, without touching and causing friction. In its best form, its paddles incline backward, so as to be nearly upright at the time the water is discharged from them into the upper channel. It has been

much used in Holland, where it is driven by windmills, for draining the surface water off from embanked meadows. In England it has been driven by steam-engines; and in one instance, an 80-horse-power engine, with 10 bushels of coal, raised 9,840 tons of water 6 feet and 7 inches high in an hour. This is equal to more than 29,000 lbs. raised one foot high per minute by each horse-power, showing that very little force is lost by friction in the use of the flash-wheel." *

A different example of draining by power is exhibited on the Middle Level Drainage Canal, where the waters are discharged over the top of the embankment through 16 parallel syphons, each 3½ feet bore, and 1⅛ inch thick. The summits of the syphons are 20 feet above, and their lower ends 1½ foot below, low water of spring tides. They have flap-valves opening down stream at both ends, and the lower valve can be made fast with a bridle when required. The air is exhausted from their summits, when required, by an air-pump having three cylinders of 15-inch diameter and 18-inch stroke, driven by a high-pressure steam-engine of 10-horse power. The flow of the canal at the inlets and outlets is protected by a wooden apron.

TIDES.

Lunar hours after high water.	Time commonly called
0	High water.
1½	Quarter ebb.
3	Half ebb.
4½	Three-quarters ebb.
6	Low water.
7½	Quarter flood.
9	Half flood.
10½	Three-quarters flood.
12	High water.

* Thomas's "Farm Implements."

TABLE FOR FINDING THE HEIGHT OF THE TIDE AT ANY INTERMEDIATE HOURS OR HALF-HOURS BEFORE OR AFTER HIGH TIDE.

Range	h. m. 6 0	h. m. 5 30	h. m. 5 0	h. m. 4 30	h. m. 4 0	h. m. 3 30	h. m. 3 0	h. m. 2 30	h. m. 2 0	h. m. 1 30	h. m. 1 0	h. m. 0 30
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
High-water	8 0	7 10	7 4	6 9	6 0	5 0	4 0	3 0	2 0	1 3	0 8	0 2
	9 0	8 9	8 3	7 7	6 8	5 8	4 6	3 5	2 4	1 5	0 9	0 3
	10 0	9 9	9 2	8 5	7 5	6 3	5 0	3 9	2 7	1 7	0 10	0 3

The first column gives the several ranges of high water; the low water is supposed to be zero at 6 hours after high water.

CHAPTER X.

EMBANKING.

The work of embanking may be considered under three heads. 1. Embanking lands against the sea. 2. Embanking against land water, or floods. 3. Protection of river banks.

1. *Embanking Lands against the Sea.*—This is a necessary preliminary to the cultivation of all the low-lying lands which are within the wash of the tides, both on the sea-coast and on the banks of tidal rivers. As upon very low flat land, with but a slight fall to seaward, much of the success of an intake depends upon its capability for drainage, the rainfall of the district is an important consideration in such undertakings. A dry climate renders less necessary the means of drainage, whilst a wet climate adds greatly to the difficulty of the situation; still, this objection only involves the question of a greater number of sluices, which are no great expense, and may be aided by steam.

The Line of Direction for a Sed-dam.—This should be considered with reference not only to the extent of the ground to be embanked, but also to its exposure with respect to the prevailing winds. Care should be taken that no abrupt angles or bends be formed, but that

their line of direction should be carried in easy curves.*

A still more important consideration in the line of a sea-bank or dam, is its situation with reference to low water, since on that depends the drainage of the lands embanked. The bank should invariably be placed, if practicable, at such a distance back as to leave a solid foreshore. The foreshore is "that portion of the ooze, slob, saltings, or mud-banks which is left unembanked, or on the sea side of the embankment. And there is no feature appertaining to a sea-bank of greater importance than this, since it acts as the advanced-guard to the bank itself, receives the first shocks of the sea, and deadens its force upon the bank, by decreasing the depth and bulk of the wave. The greater, therefore, the width of the foreshore, and the higher above low-water mark, the greater its protection to the bank. In Essex, a county so famous for its sea-banks, the foreshore generally stands several feet above low-water mark, and some hundreds of yards outside the bank; and where it wears away, its edges are scarped and stoned to prevent the loss of so valuable a defence to the sea-dam."† For fuller details on all the points involved in the construction of embankments, the student is referred to Mr. Wiggins's treatise, of which this chapter is in part a summary.

Weight of Dam.—The weight of the dam must be sufficient to counterbalance the weight of the sea against it, that weight being augmented by winds. This condition of weight is so important, that in some cases of light material, such as peat or some kinds of sand, the

* D. Stevenson, C.E., "On the Reclamation and Protection of Agricultural Land."

† "On Embanking Lands for the Sea." By John Wiggins. Published by Messrs. Crosby Lockwood & Co

safety of the bank entirely depends on it; and, in general, a bank must be *rendered* weighty in proportion to the lightness, looseness, or want of adhesion of the materials of which it is composed, either by its bulk, or by means of more weighty materials, such as stone, laid upon the lighter materials.

The force of the sea water pressing against a bank will be in the compound ratio of its depth and its velocity. Every attempt to reduce these to calculation will be in some degree nugatory, because either may at times exceed the other; but they often act in combination. The bank therefore must be superior to their greatest united strength.

The weight of sea water is $64\frac{1}{4}$ lbs. per cubic foot. The weight of earth—that is, gravel, sand, and clay mixed—is from 2,500 to 3,500 lbs., or from 1·1 to 1·6 ton per cubic yard. If the weight is 1·5 ton per cubic yard, it will be $373\frac{1}{3}$ lbs. per cubic foot. We may, therefore, take the weight of the materials usually employed in building a sea-dam, to be five or six times the actual weight of the quiescent water they have to sustain.

The weight of quiescent water is, however, but a portion of the pressure exerted on the dam; the pressure of wind upon the surface of the sea, and the velocity thus acquired by the waves, produce such a momentum that a vast increase of strength is requisite in a sea-bank to enable it to sustain the weight it will inevitably have to encounter, especially as the bank must not only be equal, but have a power of resistance superior to the most extraordinary augmentations of weight and force of water that can in any likelihood be produced by wind, tides, or currents.

A hurricane has a velocity of 80 miles an hour, and

its force is 31·490, say $31\frac{1}{2}$ lbs. per foot; but hurricanes of nearly double this pressure have been recorded. Taking these as average and extreme pressures, let us suppose this increased weight applicable, not only to the surface to which in strictness it would be nearly limited, but to every cubic foot of the whole depth of the dam; in which case it is evident that the pressure of the water will be increased by the wind up to $95\frac{3}{4}$ lbs., or even 127 lbs., per foot. This will be resisted by the dam, which is of much greater superficial extent, and of much greater weight per cubic foot, than the water pressing upon it, and therefore perfectly able to bear its force increased by the action of the wind.

Materials.—The dam may be constructed of almost any firm materials which will compact solidly together, the best, perhaps, being a mixture of clay and sand. All combinations of walls of masonry with embanking should invariably be avoided, as it is impossible to effect any proper bond or union between the earthwork and the masonry, and such composite structures are likely to result in a failure. (*Stevenson.*)

In cases where the material is not very trustworthy, a dyke, or wall of common puddling, should be carried up in the centre of the dam, of such width, and commencing at such depth below the shore level, as the case may seem to require.

Form of Dam.—The general form of a sea-dam should be such as to receive the waves easily, *i.e.* without any great concussion, or with the least degree of concussion; such as may enable the top of the wave at its highest range to run along the top of the bank without meeting with any great resistance or sudden check.

Width of Dam.—The width of the seat or base of

the dam should be regulated by the amount of adhesiveness in the material upon which it is placed, and of which it is built; because it is necessary to guard against any escape of those materials from the drawing out or suction of the sand, by the reflux of the wave, or by the soakage of water under the bank.

The width of the *top* of the bank must, in like manner, within certain limits, depend greatly on the nature of the material used in building it. This is of less consequence in those Fen districts where the top of the embankment has to serve as a roadway, and must, necessarily, be of a great width in any case. In other cases, however, where no such roadway is required and where the materials employed in constructing the bank compact well together, a top width of three feet will be amply sufficient.

Height of Dam.—In regulating the height of an embankment, it is necessary to ascertain the highest point of flood tide, making the summit of the dam about two feet higher than flood level. Embankments settle from $\frac{1}{12}$th to $\frac{1}{5}$th, and this shrinkage must be allowed for in reckoning the final height of the dam.

Slope.—The slope of the bank to the seaward is one of its principal features of strength and safety. Wiggins considered that a slope of 5 to 1 is the best that could be given to any sea-bank; that more was generally unnecessary, but that less was insufficient in exposed situations. In practice, however, it is seldom that the slope given is greater than 3 to 1 towards the water, and 2 to 1 towards the land. The slopes given to the two sides should be such as, if produced, would form an angle at the top of at least 90 degrees; otherwise the upper portion of such bank is liable to be broken away by the pressure of water,

which is always at right angles to the face of the slope.*

Delph.—The delph or drain which is dug on the land side of the sea bank or dam for the double purpose of a drain and a fence, should not be too near the foot of the bank, otherwise it may favour percolation of water under the bank, or it may cause the base of the bank to slip and give way. The usual dimensions of the delph when cut, independently of its materials, are 12 feet wide at top, 6 feet wide at bottom, and 4 or 5 feet deep. For a fence against cattle, 3 to 4 feet depth of water is requisite.

Sections of Sea-dams.—Fig. 53, a sectional diagram of a sea-bank, which is here reproduced from Mr. Wiggins's work "On Embanking Lands from the Sea," is, in its general form, supposed to fulfil all the foregoing conditions. It is, however, much too elaborate an affair for an ordinary embankment.

A plain embankment, such as is shown in Fig. 54, 7 feet high, and with a slope of 3 to

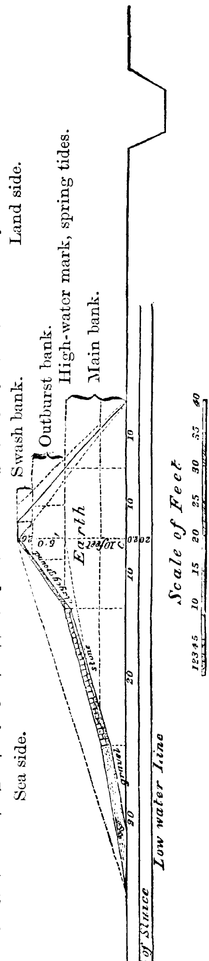


Fig. 53.

* Mr. Baldwin Latham.

1 seaward, was constructed on a coast estate in Demerara last year (1882), at a total cost of 15·62 dollars per lineal rod, and is found to answer its purpose very effectively. This dam was built without the aid of either wheel-

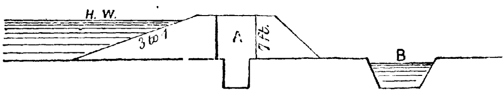


Fig. 54.

barrows, cart and horses, or tramway waggons; the earth used in banking being carried in baskets on the heads of coolies. In this country, where labour is applied differently, the cost would have been considerably less for a bank of the same dimensions.

Labour and Construction.—The labour attending the construction of a sea-bank is performed in this country by gangs, generally consisting of six runners to two fillers, a lad to clear barrows and planks, and three men to pack on the bank; these proportions, however, somewhat differing with the hardness of the soil, the length of run, and other circumstances.

The rate at which the work may be expected to advance, if no special difficulties occur, may be estimated for each filler or shoveller at about

20	cubic yards of	loose sand or mould	per day.
18	,,	compact earth	
16	,,	ordinary clay	
14	,,	hard clay	
12	,,	mud	

Tipping must be done over the end of the bank, and not over the sides. If an embankment has been made too narrow, it will not do to tip over the side, as in Fig. 55, to make it up, as the earth will tend to slip away

from the end-tipped mass. It is, however, allowable to form two narrow embankments and fill up the gap between them, as in Fig. 56.

2. *Embanking against Land Water, or Floods.*—Not only do tidal lands require to be embanked against the

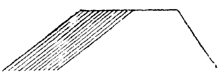


Fig. 55.

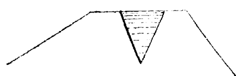


Fig. 56.

sea, but, in most cases, they require to be as carefully protected from waters which come down from the higher grounds lying aback of them, and from the risk of inundation by the overflow of rivers, &c., during floods. In countries where the rainfall is heavy, these flat lands, if they are to be safely cultivated, may require this protection, although there are neither rivers nor high grounds in the immediate neighbourhood aback of them. This is the case in Demerara, where, during wet weather, the rainfall accumulates on the level Savannah behind the estates, and, seeking its natural outlet to the sea, would completely swamp the cultivation if not shut out by an embankment. The embankment in this case is termed the back-dam, to distinguish it from the front, or sea-dam. And as the Savannah waters often gather to a great depth behind the embankment, the requisite height of the back-dam may be as great as that of the front-dam, but less weight of bank will generally suffice for the back-dam. A (Fig. 57) represents a cross section of an embankment for this purpose, the materials for which are obtained by digging a pair of trenches, B, C, alongside of it. B, which is within the intake, serves either as a

navigation trench, or for collecting surface water and discharging it into the nearest drainage channel. C is on the outer, or Savannah side of the embankment, and

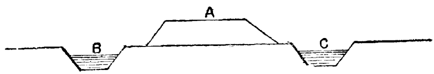


Fig. 57.

by retaining water after floods, serves as a fence and a protection to the dam from the trampling of cattle and other animals.

3. *Protection of River Banks.*—The tendency of a running stream to rapidly undermine and wash away a sandy, or earthy bank, when the latter is opposed to the direction of the current, is a matter of daily observation in most districts. This action is greater in some rivers than in others, and is not altogether regulated by the geological formation of the bank; but is influenced by the velocity of the stream, the velocity again being influenced by the fall or slope of its surface, and also by its hydraulic mean depth.

An "Agricultural Engineer," writing to the *Albany County Gentleman,* makes some very practical remarks on this subject, which we cannot do better than repeat in his own words. "The course of a stream," he points out, "is subject to the same law which controls the reflection of a moving body, which may strike an obstacle at any certain angle." This law is that "the angle of reflection is equal to the angle of incidence." In the case of a glancing ball on a smooth pavement, the course of the ball is changed by the effect of gravitation after it is reflected, and gradually assumes a curve until it reaches the ground again. So the course of a stream is influenced by

the momentum and force of its current, which is, in fact, the force of gravitation. To this variation is due the sweeping curves we see in the bends of streams, and which continually enlarge by the erosive action of the current until the land is washed away very considerably, and much damage done.

"At Fig. 58 is given a diagram of a very common form of the bed and banks of a stream passing through alluvial soil, whether of sand, gravel, or clay. The stream passing the first bend, strikes the bank A, and instead of being deflected at the same angle at which it strikes the bank, it turns with a sweep down stream in the direction of C, but is forced by the resistance of the bank into the gradual curve shown. Passing this curve it strikes again at B, and the erratic course is

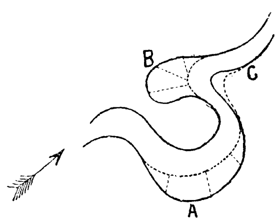


Fig. 58.

repeated. Now in these sweeps the water is forced with considerable violence against the banks, and quickly wears them away, carrying the soil in its whirls and eddies to the opposite side of the stream, where it is deposited, and is formed into an obstacle which still further aids in the work of cutting, until, in the bend shown, it would be carried down the stream to the point C.

"There are two ways of managing a stream of this

kind, one by protecting the banks from the erosive effects of the current and preserving them in *statu quo*, or forcing the stream to repair its own damages; and the other is to reform the banks altogether, and by cutting off the bend to recover a good deal of land from the stream.

"The former is best done by means of stakes and brush planted in the stream, as shown by the dotted lines in Fig. 58. It depends somewhat on the size of the stream how this work is to be done; for small streams it may be sufficient to plant rows of stakes in the bed, as shown by the dots, and interweave brush between them. The stakes may be driven at such distances apart as will suit the size of the brush. Evergreen limbs and branches, especially those of Hemlock and Spruce, are the most effective. If plenty of stones are near, the space behind these stakes and walls of brush may be filled in with them. The effect of these obstructions is greatly to retard the current behind the brush work, but not to shut out the water altogether at first. This will cause the water to deposit sediment, and in time wholly cover the stones and inner bush, and form a new and solid bank. This will be helped very much by repeated deposits of brush and stones on the edge of the old bank, gradually extended out, until the further line of brushes reaches where the final bank is to be made. As the bank forms, it is well to plant willow stakes in it, which will root and grow, and the interlacing roots will hold the soil until it becomes firm and compact. When the final bank is reached, a permanent planting should be made upon it; the older trees cut down and the soil thus made seeded to grass. The work will then be kept permanent by careful protection of washing and

strengthening the bank as may be needed. In the case of an abrupt bend, as at c, it would be well to cut off a part of the point and drive willow stakes across it, so as to form a more gradual bend, and by starting a cutting at the point to set the stream at work to finish its own repairing.

"The latter method mentioned (the reforming of the banks) may be done by cutting out a new channel across the neck of the bend in either of the directions shown by the doted lines in Fig. 59, as may be found

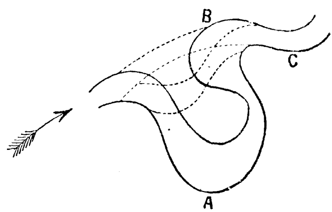


Fig. 59.

most convenient. The course of the new channel should be well studied out, and the beginning of it so placed with regard to the course of the entering current that the stream will be led easily into the desired direction.

"The old channel should not be closed altogether, but should be obstructed, as previously mentioned, so as to cause the stream itself to complete the work of closing it, which will be finally accomplished after a few successive floods. But these must be controlled in a proper manner, lest the work done through several years may be undone in a day."

The washing away of the river banks by the scouring or abrading action of the stream, may be prevented by

proceeding in very similar lines to those above recommended for remedying such an evil. Stakes and brush may be planted at the edge of the stream where any portion of the bank is threatened, or a sufficient weight of stones may be piled up, with a good effect, giving the pile height and slope enough to withstand the flow of the river in times of flood. If the stream is not deep, in dry weather, the river will probably furnish a plentiful supply of stones for this purpose. Flat or oval-shaped stones, of a small size, resist the current better than large angular ones.

APPENDIX.

1.—Elkington's System.

Elkington, called the father of under-draining, introduced his system about 1764. His theory was, that water from springs was the cause of wetness in land; that the direction of the springs was to be ascertained, and then tap them by boring into them with an auger where they are below the depth of the ditch. Johnstone states that Elkington's principles depend chiefly on three things:—

1. Upon discovering the main spring, or source of the evil;

2. Upon taking the subterraneous bearings; and

3. By making use of the auger to reach and tap the springs when the depth of the drain is not sufficient for that purpose.

"The first thing, therefore, to be observed is, by examining the adjoining high grounds, to discover what strata they are composed of, and then to ascertain as nearly as possible the inclination of these strata, and their connection with the ground to be drained, and thereby to judge at what place the level of the spring comes nearest to where the water can be cut off and most readily discharged. The surest way of ascertaining the lay, or inclination, of the different strata is by examining the bed of the nearest stream and the edges of the banks that are cut through by the water, and any pits, wells or quarries that may be in the neighbourhood. After the *mainspring* has been discovered, the next thing is to

ascertain a line on the same level to one or both sides of it, in which the drain may be conducted, which is one of the most important parts of the operation.

"*Lastly*, the use of the auger, which, in many cases, is the *sine qua non* of the business, is to reach and tap the spring, when the depth of the drain does not reach it, where the level of its outlet will not admit of its being cut to a greater depth, and when the expense of such cutting would be great and the execution of it difficult."

According to these principles, says Johnstone, this system of draining has been attended with extraordinary consequences, not only in laying the land dry in the vicinity of the drain, but also springs, wells, and wet ground at a considerable distance, with which there was no apparent connection.

2.—The Deanston System.

Thorough drainage was brought especially into notice by the late Mr. Smith, of Deanston, in Scotland, about 1832. His system briefly stated was as follows:—

"1. *Frequent* drains at intervals of from ten to twenty-four feet.

"2. *Shallow* depth, not exceeding 30 inches, designed for the single purpose of freeing that depth of soil from stagnant and injurious water.

"3. *Parallel drains at regular distances* carried throughout the whole field, without reference to the wet and dry appearance of portions of the field, in order to provide frequent opportunities for the water, *rising from* below and falling on the surface, to pass freely and completely off.

"4. *Direction of the minor drains*, 'down the steep,' and that of the mains along the bottom of the chief hollow, tributary mains being provided for the lesser hollows.

"The reason assigned for the minor drains following the line of deepest descent was, that the stratification generally lies in sheets at an angle to the surface.

"5. *As to material.*—Stones preferred to tiles and pipes."

3.—The Deep-Drainage System.

Mr. Josiah Parkes was the early advocate of deep drainage. As compared with the Deanston method, Mr. Parkes was in favour of:—

1. *Less frequent drains*, at intervals varying from twenty-one to fifty feet, *with preference for wide intervals.*

2. *Deeper drains at a minimum depth of four feet*, designed with the twofold object of not only freeing the active soil from stagnant and injurious water, but of converting the water falling on the surface into an agent for fertilizing; no drainage being deemed efficient that did not both remove the water falling on the surface and keep down the subterranean water at a depth exceeding the power of capillary attraction to elevate it to near the surface.

3. *Parallel arrangement of drains*, as advocated by Smith, of Deanston.

4. *The advantage of increased depth*, as compensating for increased weight between the drains.

5. *Pipes of an inch bore*, "*best known Conduit*" for the parallel drains.

6. The cost of draining uniform clays, he held, should not exceed £3 per acre.

4.—The Keythorpe System.

The peculiarities of the Keythorpe system of draining, as described by Mr. Trimmer, consist in this, that the parallel drains are not equidistant, and that they cross the line of the greatest descent. The usual depth is three and a half feet, but some are as deep as five and six feet. The depth and width of interval are determined by digging trial-holes, in order to ascertain not only the depth at which the bottom water is reached, but the height to which the water rises in the holes and the distance at which a drain will lay the hole dry. In sinking these holes, clay-banks are found with hollows or furrows between them, which are filled with a more porous soil, as represented in the annexed sectional diagram.

The next object is to connect these furrows by drains laid across them. The result is, that as the furrows and ridges here run along the fall of the ground, which I have observed to be the case generally elsewhere, the submains follow the fall and the parallel drains cross it obliquely.

The intervals between the parallel drains are irregular, varying in the same field from 14 to 21, 31, and 59 feet. The distances are determined by opening the diagonal drains at the greatest distance from the trial-holes at which experience has taught the practicability of its draining the

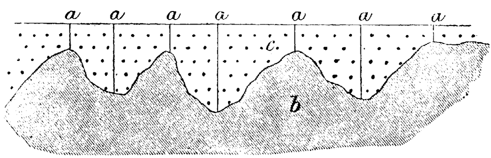


Fig. 60.

hole. If it does not succeed in accomplishing the object, another drain is opened in the interval. It has been found, in many cases, that a drain crossing the clay-banks and furrows takes the water from holes lying lower down the hill—viz. it intercepts the water flowing to them through these subterranean channels. The parallel drains, however, are not invariably laid across the fall. The exceptions are on ground where the fall is very slight, in which case they are laid along the line of greatest descent. On such grounds there are few or no clay-banks and furrows.

Judge French, in his work on drainage, says of this system: "It is claimed by its advocates that it is far cheaper than any other, because drains are only laid in the places where by careful examination beforehand, by opening pits, they are found to be necessary; and that is a great saving of expense, when compared to laying the drains at equal distances and depths over the field."

Against what is urged as the Keythorpe system several allegations are brought.

In the *first* place, that it is in fact *no system.* Mr. Denton having carefully examined the Keythorpe estate, and the public statements of its owner, asserts that the drains there laid have no *uniformity of depth,* part of the tiles being laid but 18 inches deep, and others 4 feet and more, in the same field.

Secondly,—that there is no *uniformity as to direction*; part of the drains being laid across the fall and part with the fall in the same fields, with no obvious reason for the difference of direction.

Thirdly,—that there is *no uniformity as to materials*; a part of the drains being wood, and a part tiles in the same field.

Finally, it is contended there is no saving of expense in the Keythorpe draining over the ordinary mode, when all points are considered, because the pretended saving is made by the use of wood, where true economy would require tiles, and shallow drains are used where deeper ones would in the end be cheaper. In speaking of this controversy it is due to Lord Berners to say, that he expressly disclaims any invention or novelty in his operations at Keythorpe.

5.—Air Drainage.

Mr. Hutchinson, in his "Practical Instructions on the Drainage of Land on Hydraulic and Pneumatic Principles," was the first to propound the theory of air drains.

"He digs a drain all round the *upper* ends of the system of drains which he has placed under and throughout the field, and this upper connecting drain is left open to the air, and so the stream of water through the drains is said to pull in a current of air through the pipes, and this is said to have a fertilizing effect upon the soil. We do not believe that any such effect will follow, for reasons which on 'hydraulic and pneumatic principles' seem to us suffi-

cient. The fact is, that all drainage is 'air drainage; and that, indeed, so far as the opening of a drain at its upper end to the air is effectual in facilitating the passage of water through it, there is to that extent a diminished right to claim on its behalf the results of air drainage. The air will then simply pour in at the upper end and pour out at the lower end, drawn along by the current of water through it, but not one particle of it will be of any use to plants. A drain is *receiving* at all its pores and cracks throughout its course. Nothing that is in it has any chance of getting upwards into the soil above it. Whatever enters will find its exit at the outfall; it has already done its work so far as the soil is concerned, and the sooner it is got rid of the better. That is the reason why drains are made straight down the hill. The air which does good to plants, is that which enters the surface of the soil and permeates both it and subsoil dissolved in the water which thus traverses both, or drawn in after it as it sinks. If the drain were full of water from top to bottom, then the whole weight of *that* water, as well as of what existed in the soil, would be helping to press onwards out of the soil, and helping to pull air in. If in such a case you facilitated the passage of water through the drainage tube, by opening its upper end, you would destroy the influence, whatever that may be, which the weight of water in the tube would exert in pulling air and water after it through the land. All that the water in the pipe would do in such a case, would be to pull in at its upper end and set it free at its lower end. We do not believe that the weight of water in the drainage tube has any effect whatever except in inducing its own escape The true agent in the drainage of the land is the weight of water within the soil. Let that have a chance of making its escape below the subsoil, and it will draw air after it, and introduce an activity into the soil considered as a laboratory, which will tend much to its powers of feeding the plants growing within and upon it. The circumstance of the exit pipe being open at its upper

end directly to the air, if influential, must, to the small extent of its power, diminish the activity of those passages within the soil from the air to that pipe along the whole course of its length, which alone (traversing the substance of the soil and subsoil) are usefully employed in feeding the soil-laboratory with reagents, or the soil-warehouse with food."—*Agricultural Gazette.*

6.—The Mole Plough.

The following letter, in reference to this implement, appeared in the *North British Agriculturist*, of August 3rd, 1882.

"Sir,—From your account of the Agricultural Show held at Reading, I see that Messrs. Fowler have exhibited a mole-draining plough, and as I have had some experience in using one of these with horse-power, and can testify as to its usefulness, I will give my reasons for first making a trial of one, and the result that followed. I had a deal of land drained according to a fashion that prevailed at one time, namely, 4 feet deep and 30 feet apart, and I need not say did not drain the land sufficiently. I then began to consider what could make the draining more effective; and having compared the naturally dry land with the land that required draining, I found that the bottom or subsoil of dry land was all drain, and to make wet land dry, one would have to imitate the dry land bottom as near as practicable. To do this I took one of Bentall's subsoils, put into it a coulter and a mole made of steel on the top of it. I then lifted a good deep furrow with a common two-horse plough, and put three horses in the mole-plough to follow. This I did transverse to the line of the drains, and in this way I made a drain about 18 inches deep in every furrow, and the drain was put in so deep that the tread of the horses did not injure them in the least. This had a most wonderful effect in drying the land, and if done with steam power, and to a greater depth, I have no doubt land could be dried to any extent; but care should be taken not to let

the water too rapidly into the drains, for I have heard of some land drained by Mr. Smith of Deanston that was completely spoiled. He intended to make a thorough job, and put a tile in the bottom of the drains, then filled them up with broken stones to where the plough would reach; the consequence was the water went so fast it washed all the manure out of the soil.

"I have, however, no fear of the mole-plough having any such effect, for the ground will only be cut by the thin coulter, and the sides of the cut will adhere, so that the water can only percolate into the drain in a pure state, and so leave the manure in the soil.

"I wish Messrs. Fowler success with their mole-plough, for in these successive wet seasons the farmers require all appliances to keep the water from stagnating on the land to the permanent injury of their crops.—I am, &c., Dumfriesshire."

7.—Plug-Draining.

Plug-draining, like mole-draining, does not require the use of any foreign material, the channel for the water being wholly formed of clay to which this kind of drain, like that last mentioned, is alone suited.

This method of draining requires a particular set of tools for its execution, consisting of—first, a common spade, by means of which the first spit is removed, and laid on one side; second, a smaller-sized spade, by means of which the second spit is taken out, and laid on the opposite side of the trench thus formed; third, a peculiar instrument called a bitting-iron (Fig. 61), consisting of a narrow spade, three and a half feet in length, and one and a half inches wide at the mouth and sharpened like a chisel; the mouth, or blade, being half an inch in thickness in order to give the necessary strength to so slender an implement. From the mouth, on the right hand, a steel ring, B, six inches long and two and a half broad, projects at right angles; and on the left, at fourteen inches from the mouth, a tread, C, three inches long, is fitted.

A number of blocks of wood, each one foot long, six inches high, and two inches thick at the bottom, and two and a half at the top, are next required. From four to six of these are joined together by pieces of hoop iron let into

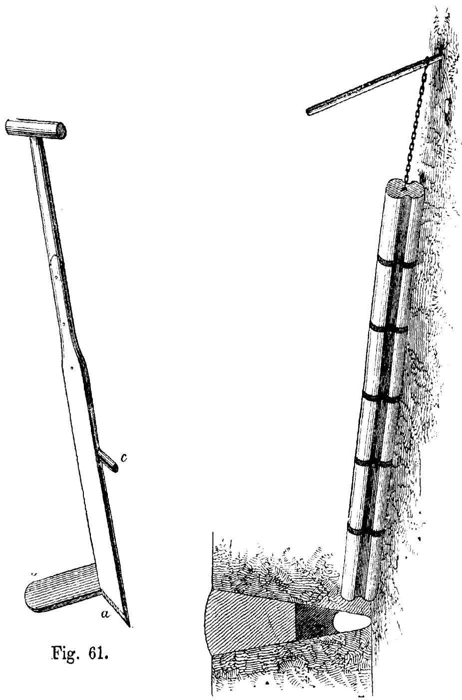


Fig. 61.

their sides by a saw-draught, a small space being left between their ends; so that when completed the whole forms a somewhat flexible bar, as shown in the cut, to one end of which a stout chain is attached. These blocks are wetted, and placed with the narrow end undermost, in the

bottom of the trench, which should be cut so as to fit them closely; the clay which has been dug out is then to be returned by degrees upon the blocks, and to be rammed down with a rammer of wood three inches wide; as soon as the portion of the trench above the blocks, or plugs, has been filled, they are drawn forward, by means of a lever. thrust through a link of the chain, and into the bottom of the drain for a fulcrum, until they are all again exposed except the last one (Fig. 62). The further portion of the trench above the block is now filled in and rammed, and so on the operations proceed until the whole drain is finished."—*Morton's Cyclopædia of Agriculture.*

8.—Drainage of Hill-Pastures.

"I consider," says the writer of a Prize Essay in the *Transactions of the Highland and Agricultural Society*, "that on hill-pastures it is desirable to allow the water-level to approach very near the surface, and that drains be only applied to remove an excess of water, with a careful regard to retain an ample supply of moisture for the continuous production of grasses. The objects to be attained are, to create for the sheep an improved pasturage, pure water, and a healthy atmosphere, which would allow of their being kept in greater numbers, and enable them to attain to a larger size and higher condition.

"Assuming that surface drains are most adaptable for hill-pastures, the size of the drain that combines most efficiency in proportion to its cost, for ordinary purposes, is 24 inches wide at top and 6 inches wide at the bottom, with a perpendicular depth of 16 inches. They should be cut clean, the turf-sod being placed 10 inches from the lower side of the drain, and the bottom clearings thrown beyond it; they will thus not be liable to be dragged into the drain. Direct-action drains (viz. those put in on the quickest descent) are most effective, and should be adopted on land of first quality: such land is generally indicated

by the presence of Bull snout (tufted hair grass), Blue-point (tufted bog or blue-edge), Wild Scavy (devil's bit), Spart (blunt-flowered rush), and common rush: and any danger of such drains washing deep can be avoided by putting them in, not more than 9 yards apart, and not running them extreme distances ere they are delivered into main drains. The cost of such drainage is too great for poor or peaty surfaces, producing little but Stool-bent (goose-corn), Deer Hair (marsh spiked rush), Wire-bent and Flying-bent (blue-bent); but on such ranges, gentle declinating drains, at an angle that will allow a fall of 1 in 25, and placed 35 yards apart, may be applied with beneficial results. Flow-mosses abound in Drawling (hare's-tail cotton grass), and are benefited by having drains put in not less than 60 yards apart. These mosses require a full surface water-level, and drains at that distance will not do more than carry off the excess, whilst they will much facilitate the entry of sheep on to them, increase their scope over them, and aid their easy return to their lairs when satiated. Those drains should commence from those parts that present a sort of highway entry from the other lands; and the proper placing of the drain-sods will be here found of great importance, forming a sort of elevated platform very useful as a sheep-track, particularly in cases of snow. The important item of cost varies with the price of labour, and will range between 1*d.* and 2*d.* for 7 yards, and generally be found at 1½*d.* for that length."

9.—Drainage of Roads.

The reason that public roads remain muddy so long, till hundreds of passing waggons have cut the surface into deep ruts, is that there is no escape for the rain that falls upon them. One or more properly constructed under drains, extending lengthwise along the road, would afford a good remedy. In localities where gravel and small stones may be had the drainage may be made almost per-

fect. The falling rain will pass through the gravel bed to the drain beneath nearly as fast as it falls, and no mud can be formed. When gravel and stones cannot be procured, the water will be longer in finding its way down, but the drain will nevertheless carry off the water in a much shorter time than when it has to escape by the slow process of evaporation.

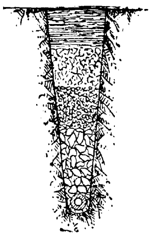


Fig. 63.

The best mode of constructing the drain is shown in Fig. 63. A good-sized pipe tile is laid at the bottom, surrounded by small stones. On these are laid smaller or broken stones or coarse gravel, then finer gravel, then soil or fine gravel at the surface. No free water can remain long on a road thus drained. A single drain in the middle of the track will often be sufficient, but for wider and more traversed roads it may be necessary to place two or even three parallel drains along the road.

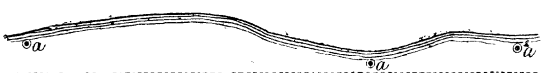


Fig. 64.

Nearly all public roads have a more or less undulating surface, and outlets must be made at every depression for the discharge of the water from the tile to the roadside. Fig. 64 represents the line of the road over a curved surface of the country. The dotted line is a level. At A A and A are springs from the tile through which the water escapes, and is discharged into the natural channels which intersect the road.—*Albany Cultivator.*

10.—On the Making and Burning of Drain Tiles.

Extracts from a communication by Mr. Law Hodges, published in the Journal of the Royal Agricultural Society of England, Vol. V. Part II.:—

"Reflecting on these obstacles to universal drainage, where required, I conferred with Mr. John Hatcher (Brick and tile maker and potter, Beneden, Kent) on the possibility of erecting a kiln of common clay that would be effectual for burning these tiles, and of cheap construction —and the result was the building one in my brickyard in July last, and the constant use of it until the wet weather at the commencement of this winter compelled its discontinuance, but not until it had burnt nearly 80,000 excellent tiles; and in the ensuing spring it will be again in regular use.

"I shall now proceed to take in order the six points enumerated under the 9th head of the Prize Essays for 1845, as printed in the last volume of the Royal Agricultural Society's Journal, viz.:—

"1st. Mode of working clay according to its quality.
"2nd. Machines for making tiles.
"3rd. Sheds for drying tiles.
"4th. Construction of Kilns.
"5th. Cost of forming the establishment.
"6th. Cost of tiles when ready for sale.

"1st Point. Working the clay.

"All clay intended for working next season must be dug in the winter, and the earlier the better, so as to expose it as much as possible to frost and snow. Care must be taken, if there are small stones in it, to dig it in small pits and cast out the stones as much as possible, and also to well mix the top and bottom of the bed of clay together. It is almost impossible to give minute directions as to mixing clay with loam, or with marl when necessary, for the better working it afterwards, as the difference of the clays in purity and tenacity is such as to require distinct management in this respect in various localities; but all the clay dug for tile-making will require to be wheeled to the place where the pug-mill is to work it; it must be there well turned and mixed in the spring, and properly

wetted, and finally spatted down and smoothed by the spade, and the whole heap well covered with litter to keep it moist and fit for use through the ensuing season of tile-making.

"2nd Point. Machine for making tiles.

"For the reasons already alluded to, I prefer Hatcher's machine. Its simplicity of construction, and the small amount of hand labour required to work it, would alone recommend it; for one man and three boys will turn out nearly 11,000 pipe tiles of 1 in. bore in a day of ten hours, and so in proportion for pipes of a larger diameter; but it has the great advantage of being movable, and those who work it draw it along the shed in which the tiles are deposited for drying, previously to their being burnt: thus each tile is handled only once, for it is taken off the machine by the little boys who stand on each side, and at once placed in the rows on either side of the drying-shed, thus rendering the use of shelves in the sheds wholly unnecessary, for the tiles soon acquire a solidity to bear row upon row of tiles, till they reach the roofs of the sheds on either side; and they dry without warping or losing their shape in any way.

"The price of this machine is £25, and it may be proper to add that the machine makes the very best roofing tiles that can be made, and at less than half the price of those made by hand, as well as being much lighter, and closer, and straighter, in consequence of the pressure through the die.

"It is necessary, in order to ensure the due mixing of the clay, as well as to form it into the exact shape to fill the cylinders of the machine, to have a pug-mill. Messrs. Cottam and Hallen make these also and charge £10 for them. This mill must be worked by a horse; in general one day's work at the mill will furnish rather more prepared clay than the machine will turn into tiles in two days.

"3rd Point. Sheds for drying.

"The sheds necessary for this system of tile-making will

be of a temporary kind: strong hurdles pitched firmly in the ground in two parallel straight lines, 7ft. apart, will form the sides of the sheds, and the roof will be formed also of hurdles placed endways and tied together at the top, as well as to the upper slit of the hurdle, with strong tarred twine, forming the ridge of the roof exactly over the middle of the shed. They must then be lightly thatched with straw or heath, and the sharpness of this roof will effectually protect the tiles from rain. Two of these sheds,

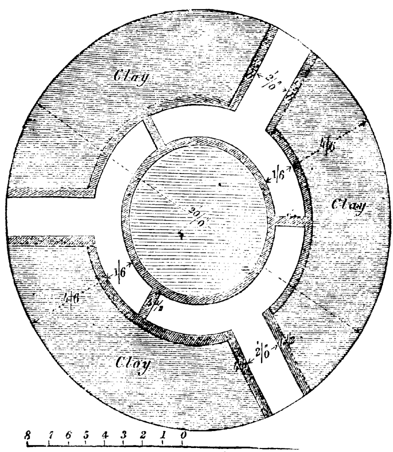


Fig. 65.—PLAN OF KILN AT A B.

each 110 ft. long, will keep one of the kilns hereafter described in full work.

"N.B.—These sheds should be so built as to have one end close to the pug-mill and the clay-heap, only leaving just room for the horse to work the mill, and the other end near the kiln. Attention to this matter saves future labour, and therefore money.

"4th Point. Construction of kilns.

"The form of the clay kiln is circular, 11 ft. in diameter

and 7 ft. high. It is wholly built of damp earth, rammed firmly together, and plastered inside and out with loam. The earth to form the walls is dug out around the base, leaving a circular trench about 4 ft. wide and as many deep, into which the fire-holes of the kiln open. If wood be the fuel used, three fire-holes are sufficient; if coal, four will be needed. About 1,200 common bricks are wanted to build these fire-holes and flues; if coal is used,

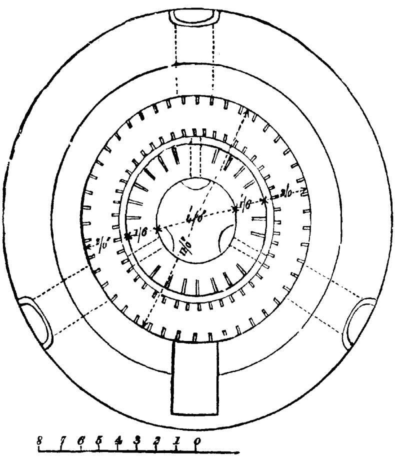


Fig. 66.—Plan of Top of Kiln.

rather fewer bricks will be wanted, but then some iron bars are necessary—six bars to each fire-hole.

"The earthen walls are 4 ft. thick at the floor of the kiln, are 7 ft. high, and tapering to the thickness of 2 ft. at the top; this will determine the slope of the exterior face of the kiln. The inside of the wall is carried up perpendicularly, and the loam plastering inside becomes, after the first burning, like a brick wall. The kiln may be safely erected in March, or whenever the danger of injury from frost is over. After the summer use of it, it

must be protected by faggots or litter against the wet and the frost of winter.

"A kiln of these dimensions will contain—

47,000	1-in.	bore pipe tiles.
32,500	$1\frac{1}{4}$	" "
20,000	$1\frac{3}{4}$	" "
12,000	$2\frac{1}{4}$	" "

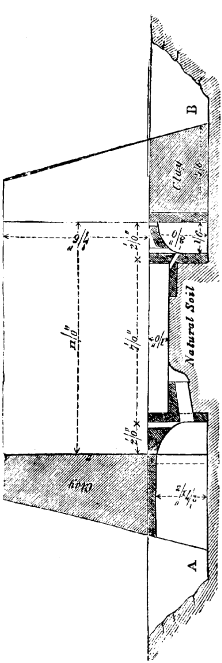


Fig. 67.—Section of Kiln.

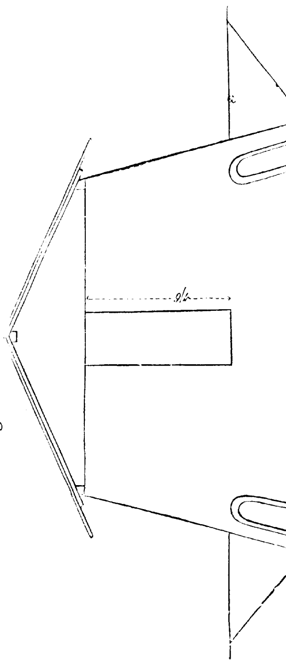


Fig. 68.—Elevation.

and the last-mentioned size will hold the same number of the inch pipes inside of them, making therefore 24,000 of both sizes. In good weather this kiln can be filled, burnt, and discharged once every fortnight; and fifteen kilns may be obtained in a good season, producing—

705,000 1-in. pipe tiles.
Or 487,500 $1\frac{1}{4}$,, ,,
Or 300,000 $1\frac{3}{4}$,, ,,

and so on in proportion for other sizes.

"N.B.—If a kiln of larger diameter be built, there must be more fire-holes and additional shed room.

"5th Point. Cost of forming the establishment.

The price charged by Messrs. Cottam and Hallen for the machine, with its complement of dies, is	£25
Price of pug-mill	10
Cost of erecting kiln	5
Cost of sheds, straw	10
	£50

(The latter item presumes that the farmer has hurdles of his own.)

"6th Point. Cost of tiles when ready for sale.

"As this must necessarily vary with the cost of the fuel, rate of wages, easy or difficult clay for working, or other local peculiarities, I can only give the cost of tiles as I have ascertained it here according to our charges for fuel, wages, &c. &c. Our clay is strong, and has a mixture of stones in it, but the machine is adapted for working any clay when properly prepared.

"It requires 2 tons 5 cwt. of good coals to burn the above kiln full of tiles. Coals are charged here at £1 8*s.* per ton, or 1,000 brush faggots will effect the same purpose and cost the same money; of course some clays require more burning than others; the stronger the clay the less fuel required.

"The cost of making, the sale prices, and number of each sort that a waggon with four horses will carry, are as follows:—

	Cost. *s.*	*d.*		Sale price. *s.*	Waggon holds—
1-in. pipe tiles . .	4	9	per 1,000	12 . .	8,000
$1\frac{1}{4}$,, . .	6	0	,,	14 . .	7,000
$1\frac{3}{4}$,, . .	8	0	,,	16 . .	5,000
$2\frac{1}{4}$,, . .	10	0	,,	20 . .	3,500
$2\frac{3}{4}$,, . .	12	0	,,	24 . .	3,000
Elliptical tile				24	2,000
Soles				80	2,000

"All these tiles exceed a foot in length when burnt.

"The cost price alone of making draining tiles will be the charge to every person making his *own* tiles for his *own* use. If he sell them, a higher price must, of course, be demanded to allow for some profit, for credit more or less long, for bad debts, goods unsold, &c. &c.; but he who makes his own saves all expenses of carriage, and, as his outlay will not exceed £50, the interest on that sum is too trifling to be regarded, and he has no additional rent to pay; and after he has made as many tiles as he wants, his machine and pug-mill will be as good as ever, with reasonable care, and will fetch their value."

11.—Drain Pipe Machine.

Fig. 69 is an engraving of Armitage & Itter's Patent Horizontal Pipe and Tile Machine, which is manufactured by Barford & Perkins, Peterborough. The machine is of a very portable construction, is easily worked by a strong

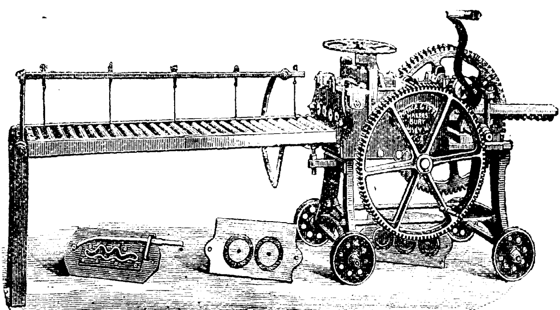


Fig. 69.

lad, and can be moved to and fro with little difficulty. The price of this machine, with long cutting table, and one pipe die of any size to 5 inches internal diameter, in cast iron, is £16 16s. The machine is also made in larger sizes at a slight increase in the cost.

12.—DATA FOR CALCULATING RAINFALL.

Inches Depth of Rainfall.	Cubic Feet on an Acre.	Gallons on an Acre.
1	3,630	22,635
2	7,260	45,270
3	10,890	67,905
4	14,520	90,539
5	18,150	113,174
6	21,780	135,809
7	25,410	158,444
8	29,040	181,079
9	32,670	203,714
10	36,300	226,349

An inch of rain is roughly equivalent to 100 tons per acre.

An inch of rain per annum on an acre is roughly equivalent to ten cubic feet per day.

Annual depth of rain-fall in different countries and seasons ranges from 0 to 150 inches.

In Britain, different seasons and districts, 15 to 100 and upwards.

Ratio of available to total rainfall on gathering-grounds: steep impervious rock, from 1·0 to 0·8, moorland and hilly pasture, from ·8 to ·6, cultivated land, from ·5 to ·4, and sometimes less; chalk 0.

Greatest depths of rain in short periods: one hour, 1 inch; four nours, 2 inches, 24 hours 5 inches.

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